VOLUME 83 NO. AT2
DECEMBER 1957

JOURNAL of the

Air Transport Division

PROCEEDINGS OF THE

AMERICAN SOCIETY OF CIVIL ENGINEERS

AMERICAN SOCIETY OF CIVIL ENGINEERS FOUNDED 1852

BASIC REQUIREMENTS FOR MANUSCRIPTS

This Journal represents an effort by the Society to deliver information to the reader with the greatest possible speed. To this end the material herein has none of the usual editing required in more formal publications.

Original papers and discussions of current papers should be submitted to the Manager of Technical Publications, ASCE. The final date on which a discussion should reach the Society is given as a footnote with each paper. Those who are planning to submit material will expedite the review and publication procedures by complying with the following basic requirements:

1. Titles should have a length not exceeding 50 characters and spaces.

2. A 50-word summary should accompany the paper.

3. The manuscript (a ribbon copy and two copies) should be double-spaced on one side of 8½-in. by 11-in. paper. Papers that were originally prepared for oral presentation must be rewritten into the third person before being submitted.

4. The author's full name, Society membership grade, and footnote reference stating present employment should appear on the first page of the paper.

5. Mathematics are reproduced directly from the copy that is submitted. Because of this, it is necessary that capital letters be drawn, in black ink, ⅛-in. high (with all other symbols and characters in the proportions dictated by standard drafting practice) and that no line of mathematics be longer than 6½-in. Ribbon copies of typed equations may be used but they will be proportionately smaller in the printed version.

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8. Papers should average about 12,000 words in length and should be no longer than 18,000 words. As an approximation, each full page of typed text, table, or illustration is the equivalent of 300 words.

Further information concerning the preparation of technical papers is contained in the "Technical Publications Handbook" which can be obtained from the Society.

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AT,BD,CP,CO,HW,IR,SU,WW,PL.

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

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December, 1957

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(Over)

Journal of the
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OPENING REMARKS[a]

Mason G. Lockwood,[1] President, ASCE
(Proc. Paper 1467)

The writer's interest in the Jet-Age Airport Conference transcends somewhat the responsibilities of the President of the Society sponsoring the conference. My practice as a consulting engineer has included considerable activity in the planning and design of airport facilities, especially at military installations.

For some time in the United States it has been quite apparent that many heads have been "buried in the sand" concerning the impending problems of the jet age in commercial aviation. Many municipal authorities, as well as those they represent, are behaving as though they believe the problems will disappear if they are ignored.

It is possible, however, that the conclusions of this conference may indicate that the end of this unguided float trip is near and that the "look, no hands" approach to the jet-related airport problems has run its course. From now on, we are playing for keeps: The jet-age airport is here.

The fact is that many municipal and other civilian jurisdications have not realistically faced the impending conversion to jet aircraft, which is so imminent. For the CAA and other authorities the problems are real and recognizable. However, for many others they are problems of the future—vague, obscure, and somewhat unreal.

Enough has been said about the 400 jet-powered airliners which the civilian aviation industry has ordered for early delivery at a cost of approximately $2,000,000,000. However, not enough has been done about them by local airport authorities.

It is no longer news that the scheduled airlines are now the primary passenger carrier in the United States, exceeding both the railroads and the intercity buses. Neither is it news that the jet age will have a revolutionary impact on commercial aviation, or that the superlative comfort and convenience of almost vibrationless flight at speeds that are nearly sonic will increase the attractiveness of air travel to nearly unimaginable numbers of new air travelers, more than 90% of whom have not yet experienced air travel in any form.

It will be news indeed, however, if the Conference is able, through its

Note: Discussion open until May 1, 1958. Paper 1467 is part of the copyrighted Journal of the Air Transport Division of the American Society of Civil Engineers, Vol. 83, No. AT 2, December, 1957.

a. Presented at The Jet Age Airport Conference, May 15-17, 1957.

1. Partner, Lockwood, Andrews & Newnam, Houston, Tex.

serious deliberations, to bring into appropriate perspective the problems which face the airport authorities in preparing for the arrival of the jet fleet.

A group more competent to grapple with these problems than those attending the Conference could hardly be assembled. Here are practical-minded engineers and other renowned specialists who know and understand the jet age because they, and their kind, have created it. They know jet aircraft because they design and manufacture them and operate them and their related ground facilities. Furthermore, they know jet aircraft because they regulate their operation and because they design and construct airport facilities essential to the use of the aircraft.

Many of the subjects to be explored and considered at the Conference go far beyond the field of civil engineering. Other branches of engineering—as well as that of architecture, the sister design profession—are closely involved. Nevertheless, it seems quite fitting that this very significant and potentially far-reaching Conference on the "Jet-Age Airport" should be convened by the American Society of Civil Engineers, the oldest of the national engineering societies. Moreover, it seems equally appropriate that the Conference should be held in the New York area, where recourse may be had to the Metropolitan Section of ASCE for the essential local impetus and imagination in such an important and original undertaking of the Society, because the Metropolitan Section cradled the American Society of Civil Engineers.

In the official capacity of President, I acknowledge on behalf of the American Society of Civil Engineers, our genuine indebtedness to the Air Transport Division of the Society and our gratitude to the Metropolitan Section and the other local sponsors. Especially, warmest thanks are expressed to all the participants and to their sponsors who have made possible their participation.

Finally, one can say in complete sincerity that the nation may be quite indebted to each of you.

Paper 1468 December, 1957 AT 2

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

ORIENTATION*

Joseph D. Blatt** A.M. ASCE
(Proc. Paper 1468)

ABSTRACT

The civil engineer must assume the responsibility of planning and designing the world's air terminals to meet the requirements imposed by the introduction of turbine powered aircraft into the civil air fleets. The Jet Age Airport Conference is designed to provide the engineer with the necessary basic design data.

In September 1956 the Executive Committee of the Air Transport Division of the American Society of Civil Engineers determined that it would be mutually beneficial to the Engineering Profession and the Air Transport Industry if a Jet Age Airport Conference were convened.

Recognizing the historical role the civil engineer has played in the development and advancement of all forms of transportation—in the highway field, railroads, rapid transit, inland waterways, and marine transportation—it was most logical to assume that the civil engineer has, today, an outstanding part to play in planning for the introduction of turbine-powered aircraft into the world's civil air transport fleets. In order to plan and design the most modern and efficient terminals to serve the aircraft of the future, the civil engineer must have a working knowledge of the operational and physical characteristics of the vehicles involved. He must know the capabilities and limitations of the navigation and traffic control facilities utilized by these vehicles. He must have knowledge of the economic soundness of the industry he is serving and he must be aware of the maintenance and service requirements of this industry. The aviation industry, if they are to do an adequate job of economic and operational planning, must be cognizant of the characteristics of the terminal designs that will be provided by the engineers. The

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* Paper prepared for presentation at Jet Age Airport Conference, New York, N.Y., May, 1957.

** Deputy Regional Administrator, Civil Aeronautics Administration, New York, N. Y.

controlling factor of operational doctrine might well be the physical characteristic of the airport to be served. The Civil Engineer must provide a balanced design so that the jet age aircraft and the forecasted traffic can be accommodated and served by our air terminals. In that way the Civil Engineer will be fulfilling his responsibilities.

The Air Transport Division, in developing the program for this Conference, invited experts from varied specialties in air transportation to come here and present a status report. These experts have been drawn from government and industry and represent the manufacturer of the vehicle, the operator of the vehicle and the provider of the terminal facilities.

Government and industry forecasters have indicated that aviation is on the threshold of a new era of expansion. Predictions, even the traditionally conservative forecasts of the Government, indicate that between 1957 and 1970 air carrier revenue passenger miles will triple, the number of passengers will triple, the volume of domestic civil air cargo will increase fourfold and business flying will more than double. The national and international economic picture promises tremendous demands for air transportation services.

The new turbine-powered aircraft, on the drafting tables and under production, will provide the air transportation industry with vehicles with increased speed and higher load-carrying capacity. Can the civil engineer provide economic and efficient terminals to handle the forecasted traffic? That is the basic question that the civil engineer should start answering today. That is the challenge.

The economists are rather convincing in proving that the demand for air-transportation services exists. It must at all times remain crystal clear that the forecasts as prepared by the economists can only be realized if the terminals are adequate. The airport must not become the bottleneck of air transportation! The Executive Committee of the Air Transport Division sincerely hopes that through the medium of this Jet Age Air Conference a better understanding of aviation's requirements will be made known to the engineering profession.

Paper 1469 December, 1957 AT 2

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

CIVIL JET TRANSPORT NOISE[a]

Donald A. Buck[1]
(Proc. Paper 1469)

INTRODUCTION

The speed, payload, and altitude capabilities of modern piston engine commercial aircraft have progressively increased to over twice the capabilities of the civil transports of 25 years ago. Now, the new four-engine civil jet transports that will soon be in operation will represent a very significant improvement in commercial air transportation. Again the speed, payload, and altitude capabilities will double. But this advancement will be in one step—and achieved primarily because of the jet engine.

Unfortunately, the sound of the jet engine is new to many people. Public opinion regarding the noise of civil jet aircraft has sometimes been formed by sensational publicity of questionable authority or been associated with the operation of military jet aircraft. But any association between civil jet transport and military jet airplane operation should give consideration to some of the basic differences in the utility of aircraft, which dictates the design and characteristics of the aircraft. Military jets are operating which have one to eight engines—many of them with afterburners and must be designed to achieve the ultimate in range, speed or altitude capabilities. The civil jets will have two or four engines with suppressors installed and must meet stringent C.A.A. requirements for takeoff, climb, safety, etc. Some of the large 6 and 8 jet bombardment aircraft have, for various reasons, a restrictive approach glide path. The Boeing 707 prototype has demonstrated approach and glide path characteristics superior to large present-day civil aircraft. The crosswind landing characteristics of some military aircraft preclude the use of preferential runways, whereas, the 707 will be as good or better than present civil transports in this respect. Fortunately, there are definite advantages to the operation of civil jet transports with respect to noise when compared to the operation of military jets or even commercial propeller driven aircraft. These advantages must be developed and exploited by the manufacturer, the airlines, the airport designers and operators and the various levels of government in order to achieve the most effective and desirable civil jet transport operation possible.

Note: Discussion open until May 1, 1958. Paper 1469 is part of the copyrighted Journal of the Air Transport Division of the American Society of Civil Engineers, Vol. 83, No. AT 2, December, 1957.

a. Presented at The Jet Age Airport Conference, May 15-17, 1957.

1. Boeing Airplane Co., Transport Div., Renton, Wash.

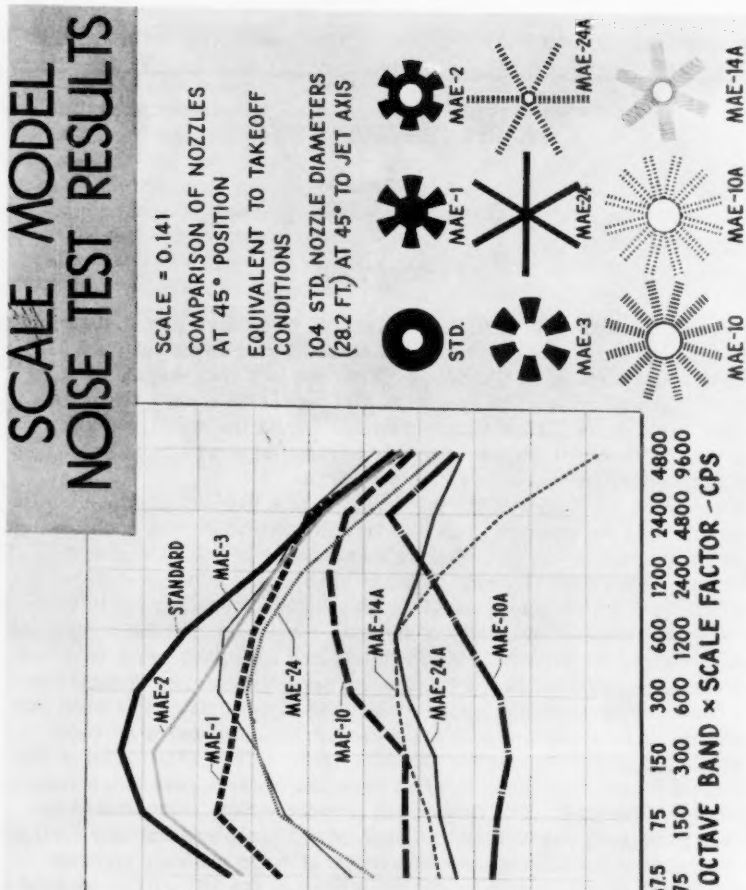


Fig. 1. Scale Model Noise Test Results.

SUMMARY

This paper will present a brief summary of the Boeing noise suppressor development program and airport terminal considerations and community considerations with respect to civil jet transport noise.

I would like to make reference to papers previously submitted by Boeing personnel on the subject of Jet Aircraft Noise which have assisted in the preparation of this presentation. These papers may be referred to for additional details of the Boeing suppressor program.

a) "Silencing the Jet Aircraft" by H. W. Withington, Chief of Technical Staff. I.A.S. January 1956.
b) "Jet Aircraft Noise" by E. N. Sidor, Staff Engineer—Electrodynamics. Munich Noise Conference, October 1956.
c) "Summary Progress Report on Jet Noise Suppression" by H. H. Howell, Chief-Acoustics and Electrical Unit, W.A.C.A. Subcommittee on Noise. February 1957.

Boeing Suppressor Development

More than forty model suppressor nozzles have been tested acoustically and aerodynamically and the results correlated with full scale testing. The use of models during the initial development program permitted a large number of different types to be tested in a short period of time at minimum cost.

Test results for several models are shown in Figure 1 which is a plot of the sound in decibels over a range of frequencies. As indicated, it has been possible to reduce the sound pressure level as much as 40 decibels at some frequencies.

It has been necessary, however, to attain the maximum amount of suppression with consideration of the complexity, weight and drag of the unit as well as its compatibility with the installation of the thrust reverser device at the jet engine tail pipe.

An example of the variation in the drag of several suppressor models is shown in Figure 2. The amount of overall airplane drag varied with the different suppressor configurations from 6% to 7% in the cruising speed range.

Full scale static and taxi tests of suppressor units were accomplished before the sale of the 707 to our first commercial customer in November of 1955. Figure 3 illustrates one of the early suppressor models mounted for static tests of thrust, fuel flow and engine operational characteristics. A number of different designs have been tested in this manner.

Figure 4 is illustrative of the sound pressure levels at various frequencies for a refined experimental suppressor as compared to a standard (unsuppressed) nozzle. In general, the suppressor designs have reduced sound pressure levels in the lower frequencies to values less than those of present large piston engined transports. The effective suppression is less, however, in the higher frequencies and the sound pressure levels are greater than the piston driven aircraft in this area. These values are representative of the maximum sound pressure level for a single engine operated at maximum thrust at a distance of 200 ft.

The overall sound contours for a suppressed jet engine operated under these conditions are shown in Figure 5. Of significance here, is that the values shown on Figure 4 are representative of the maximum point on the

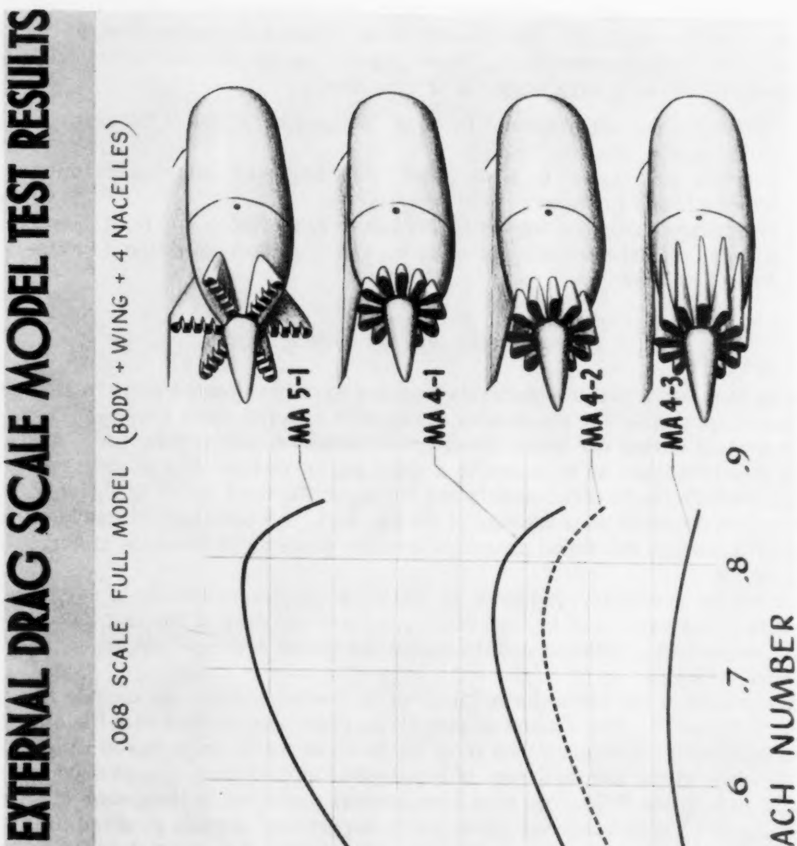


Fig. 2. External Drag, Scale Model Test Results.

Fig. 3. Test Cell Installation.

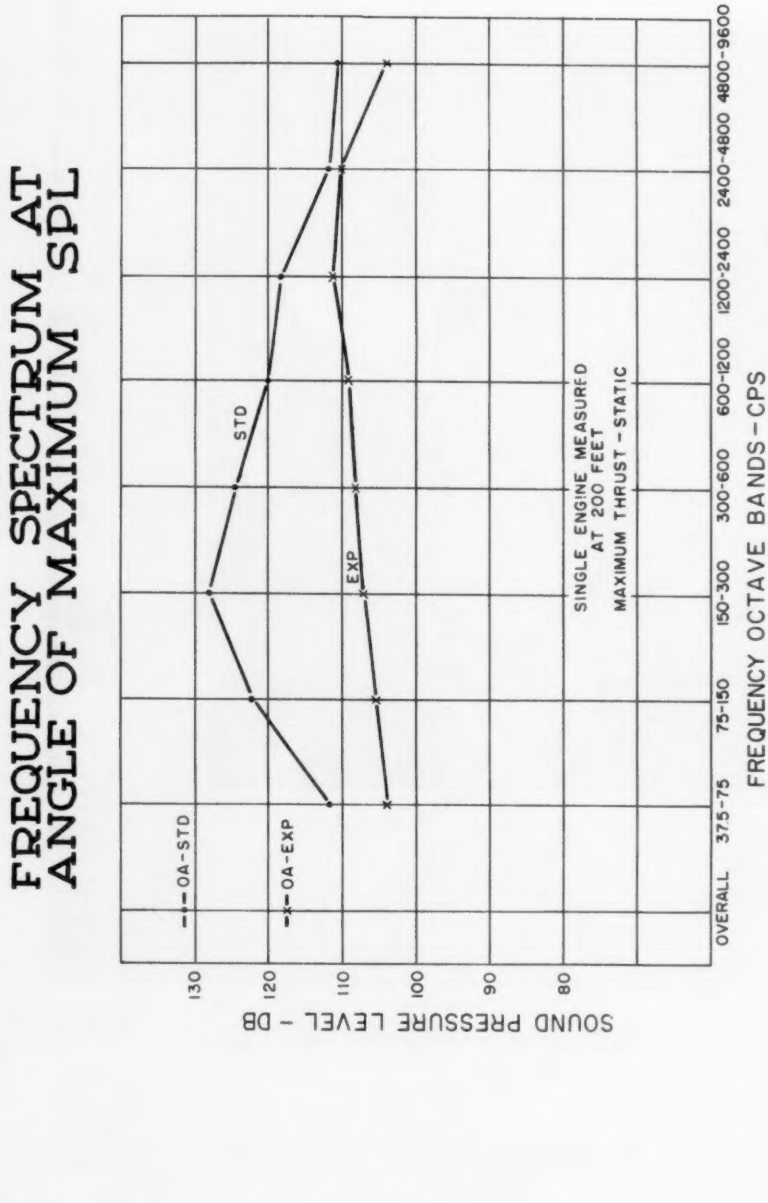


Fig. 4. Frequency Spectrum at Angle of Max. SPL.

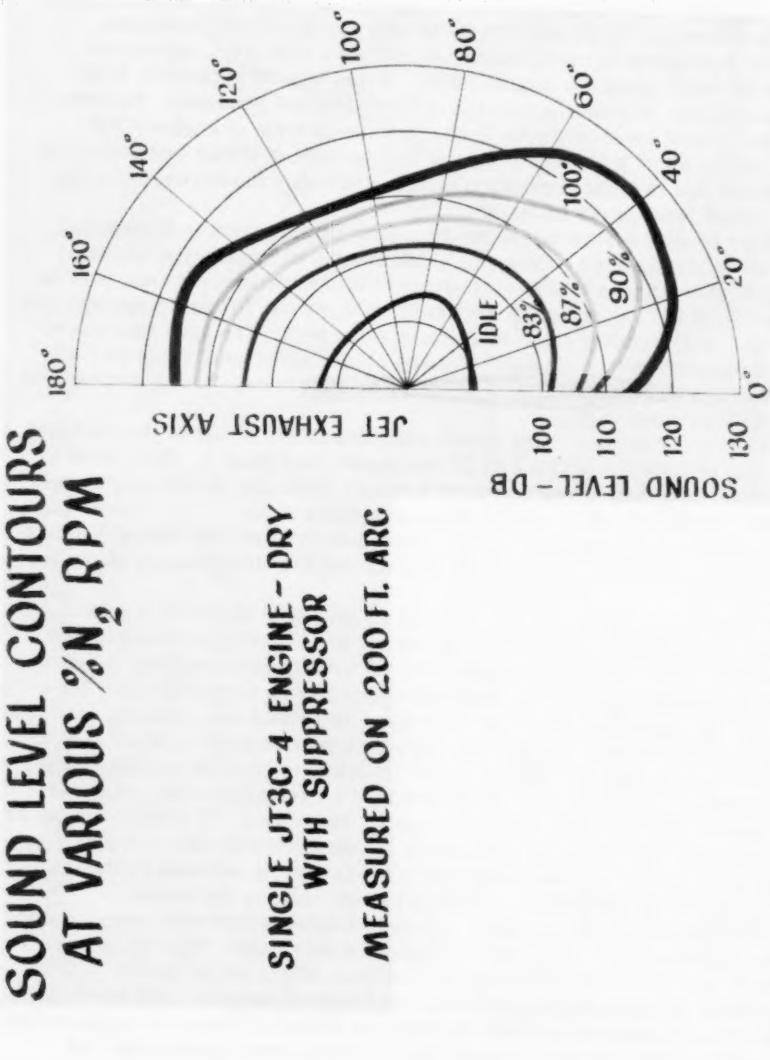


Fig. 5. Sound Level Contours.

100% power curve, which is located about 40 degrees from the exhaust axis. The sound is less at a greater or lesser angle from the exhaust axis.

The sound pressure level at 200 feet from a jet engine at full power will probably seldom, if ever, be heard by anyone but a maintenance mechanic, and he will probably wear ear plugs or other protective devices in close proximity to an engine at full power.

With consideration of terminal area noise, it is the sound pressure level contours shown for "idle" and 83% RPM with which we are concerned.

Figure 6 presents the relationship of overall sound level and engine thrust with roter speed (or engine RPM) From idle RPM to 100% RPM there is a steady increase in percent of takeoff thrust produced. However, the overall sound level increase is small at the percent of engine RPM slightly above idle. It is in this area of low percent of thrust and percent of engine RPM that terminal operation occurs and under these conditions the overall sound level is not excessive.

In order to evaluate the operation of a civil jet transport in a terminal area, Boeing constructed a concrete block simulated finger-type terminal building 80 ft. x 15 ft. x 9 1/2 ft. Fourteen different maneuvers and parking positions were accomplished on August 2, 1956, by the 707 prototype airplane and a C-97 to determine which maneuvers were best. The area was instrumented to record values of heat, blast and noise during each maneuver and these readings were summarized as shown on Figure 6A. It was determined that heat was no problem.

A tabulation of overall noise levels recorded in the inside of the terminal and outside at Gate 1 and at the C-97 are shown on Figure 7. Observers at the demonstration concluded that even a simple terminal structure was very effective in reducing sound levels to an acceptable value.

An analysis of the sound intensity and frequency spectrum during the taxi-in operation is shown on Figure 8 and illustrates the effectiveness of the terminal building.

A similar presentation for the taxi-out operation is shown on Figure 9. The noise level inside the terminal is low but the intensity at both gates remains about equal. The noise values are not greatly different than those obtained from present large civil transports and may be acceptable at a terminal with infrequent or low density traffic. The observers present, however, were interested in operation at high density airports where adjacent aircraft may be undergoing various phases of the terminal operations simultaneously and requested a demonstration of the effect of a barrier between gate positions. Boeing has developed and uses a blast fence for B-52 ground run-up as shown in Figure 10. This louvered fence is completely effective in diverting the blast from engines at full power from the taxi strip adjacent to the fence. However, the fence has little or no effect in attenuating the sound.

Figure 11 shows a similar fence which was constructed with over-lapping louvers of plywood and tested with the use of smoke pots. This fence also was effective in diverting the blast but had little effect on the noise. A low curved, solid fence is illustrated in Figure 12. Tests proved it to be of no value in attenuating sound and not suitable for blast deflection for a maneuvering aircraft. A total of six different fence designs were constructed and tested and the solid deflector shown in Figure 13 proved to be the best design and very affective in diverting both blast and noise. Eighty feet of this type of deflector fence was constructed from 8 foot plywood sheets and 2" x 4" lumber. The fence was weighted with sandbags for use during another 707 terminal demonstration held in Seattle on March 18, 1957.

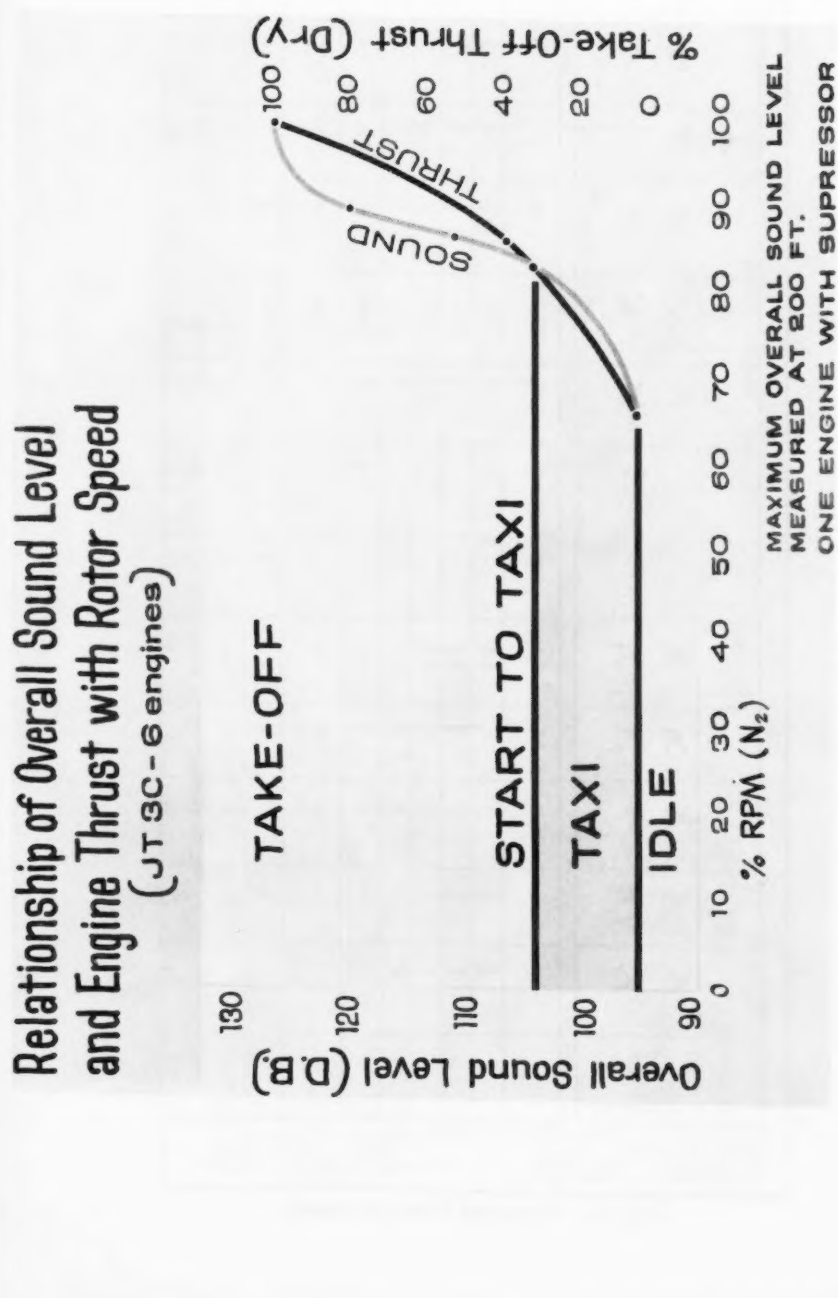
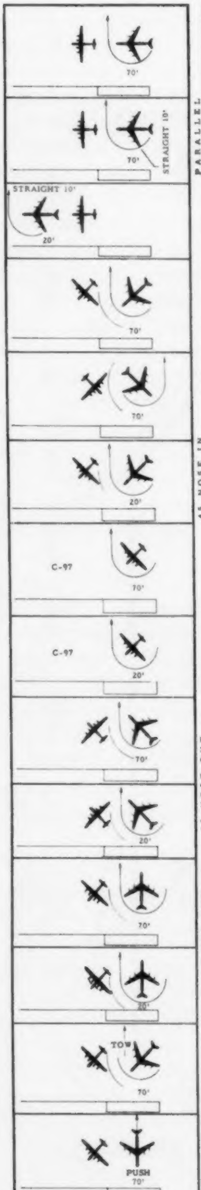


Fig. 6. Sound Level vs Engine Speed vs Thrust.



	CONDITION	THRUST 1	THRUST 2	THRUST 3	THRUST 4	TEMP.	VELOCITY	SOUND IN	SOUND OUT	NOISE RATING
	6.0	2625	2750	650	700	65°	40MPH	120 DB	123DB	OUT 3rd IN 7th
PARALLEL	7.0	2750	3050	650	700	68°	35	121	120	OUT 6th IN 5th
	2.0 (REMOTE)	2875	3025	650	700	57°	9	100	93	OUT 14th IN 15th
	3.0	2700	2700	675	700	70°	45	115	120	OUT 5th IN 12th
	5.0 5.1 5.2	650 875 675	700 800 700	2650 2150 2475	3050 2200 2775	67° 62° 74°	45 45 48	118 121	121 112 123	OUT 4th IN 11th OUT 10th IN 6th OUT 2nd
45 NOSE IN	1.0	2875	2975	975	1200	83°	60		130	OUT 1st
	11.0					58°	25	108	115	OUT 9th IN 14th
	13.0					58°	45	118	118	OUT 8th IN 10th
45 NOSE OUT	8.0 9.0	2825 3350	3050 3500	650 650	700 700	72° 78°	50 55	124 118	110 112	OUT 12th IN 3rd OUT 11th IN 9th
	8.1	2525	2525	650	700	102°	45	128	120	OUT 7th IN 1st
90 NOSE OUT	12.0	2775	2900	700	875	77°	35	124	103	OUT 13th IN 4th
	12.1	2450	2525	650	700	97°	45	127		IN 2nd
TOW OUT	4.0	2350	2250	675	700	57°	7	118		IN 8th
	10.0	1075	1200	1425	1075	57°	5	113		IN 13th

NOTES:
(1) Ambient conditions, 57 F, 4-5 MPH wind.
(2) Ramp area slope 2' - 3' away from terminal.
(3) Model FS-64 (8 lobe) Sound Suppressors installed

DIAGRAMATIC SUMMARY
707 TERMINAL PARKING DEMONSTRATION
(FROM REPORT OF TEST NO. 236-1, AUG. 2, 1956,
PRELIMINARY DOCUMENT No. D-15141)
SALES DEPARTMENT 9/14/56

Fig. 6A. Terminal Tests Summary.

TERMINAL TEST

NOSE WHEEL POSITION	OVERALL NOISE LEVELS-DB GATE #1 OUTSIDE	INSIDE	AT KC-97
1	100		100
3	105.5		107
6	110	92	109
7B	113.5	91	107
10	92		92

CIRCLED NUMBERS, ⑥, ARE NOSE WHEEL POSITIONS AT WHICH DATA COORDINATION WAS ACHIEVED

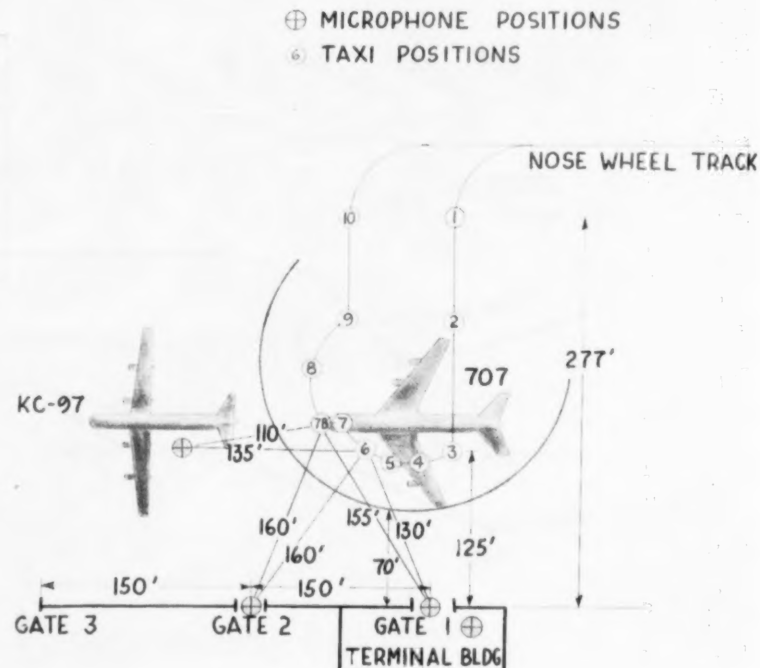


Fig. 7. Terminal Test Results.

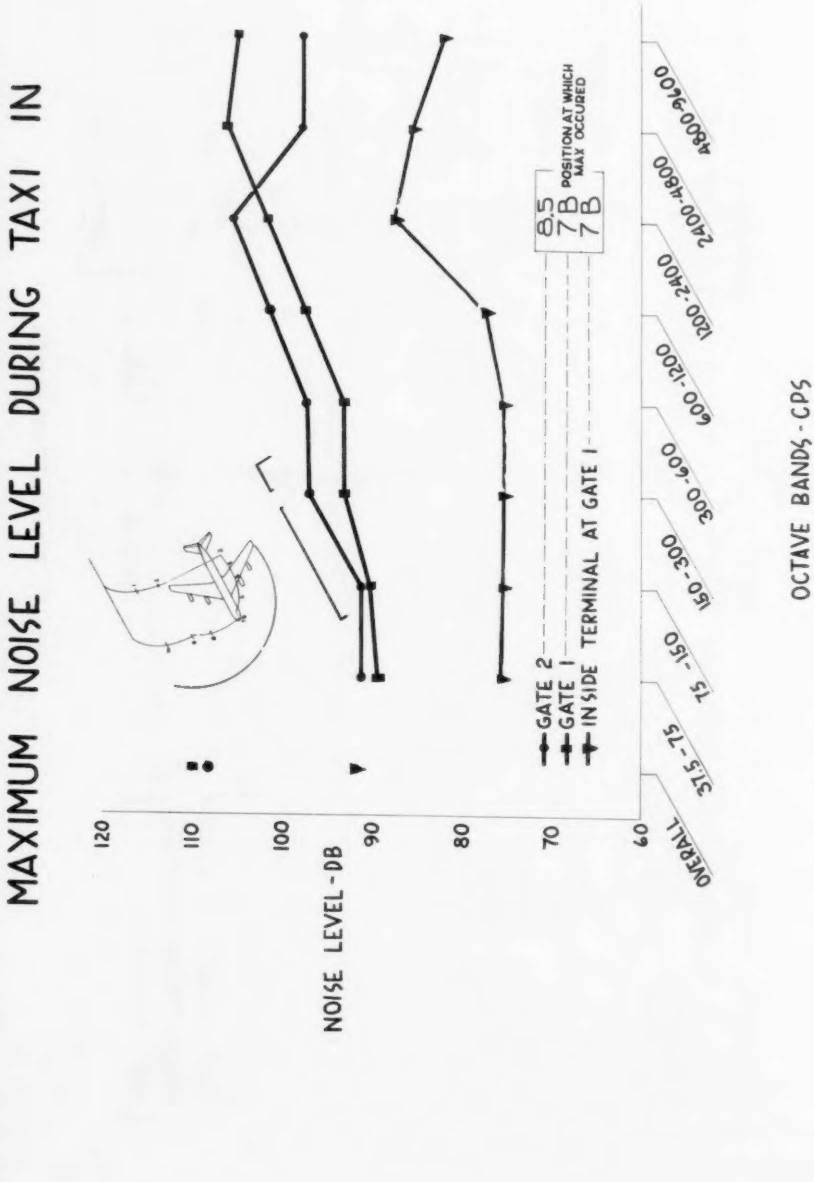


Fig. 8. Taxi-in Noise.

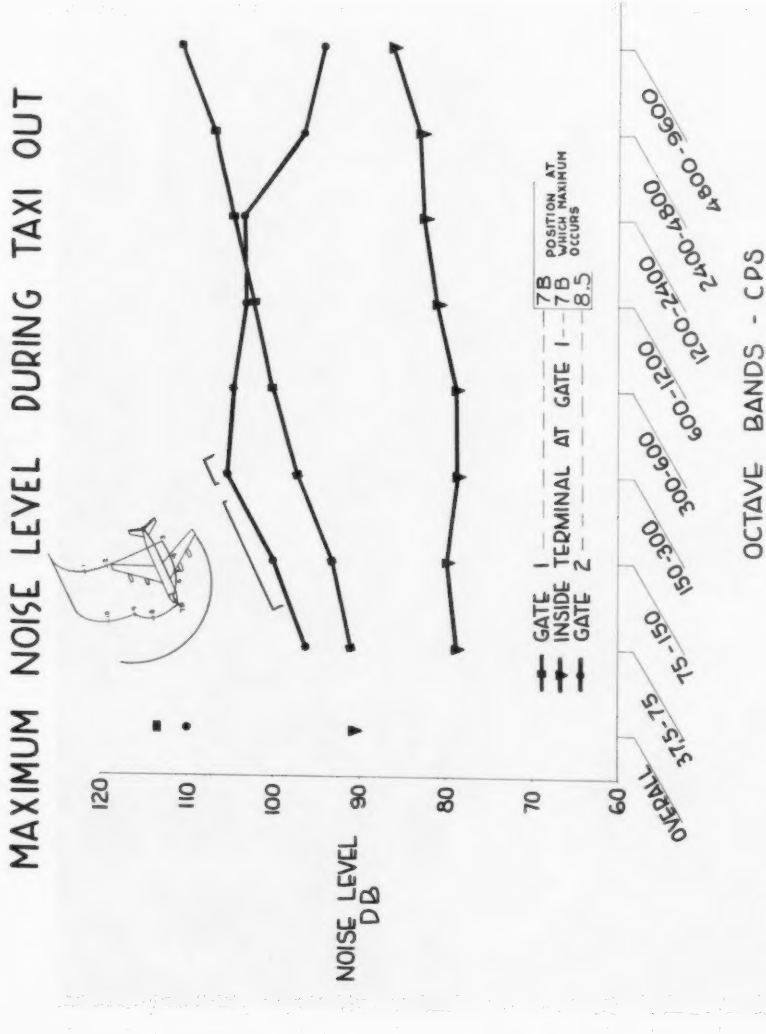


Fig. 9. Taxi-out Noise.

Fig. 10. B-52 Blast Fence.

TYPE I

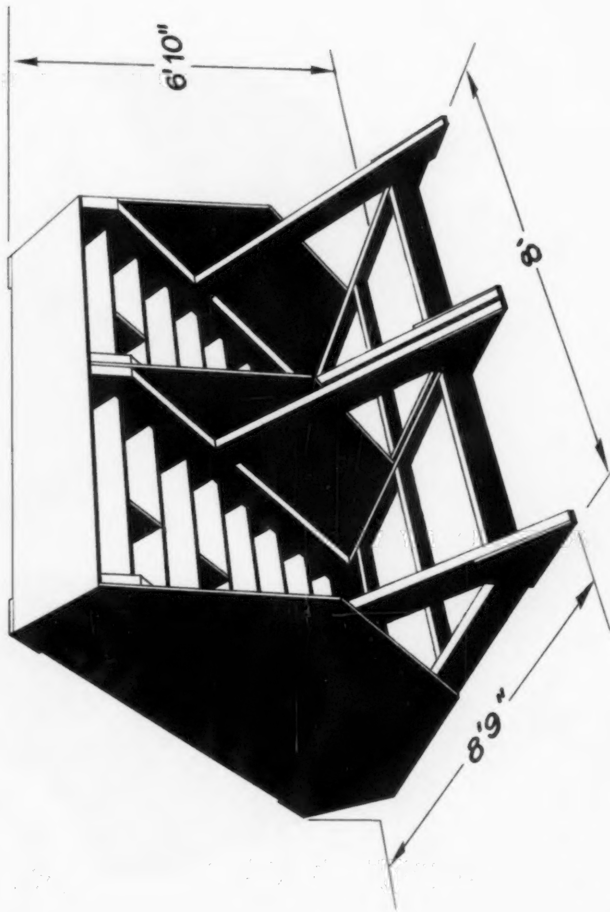


Fig. 11. Test Fence Section.

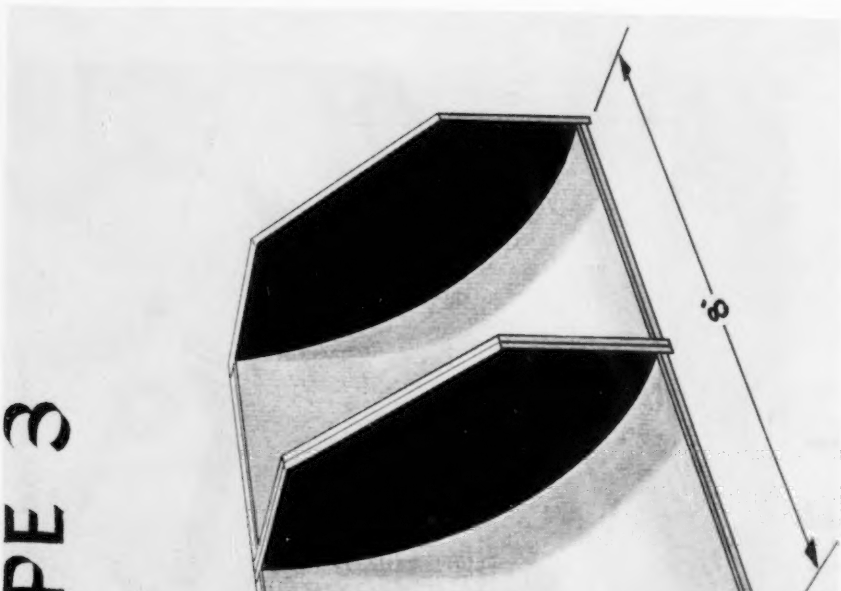


Fig. 12. Test Fence Section.

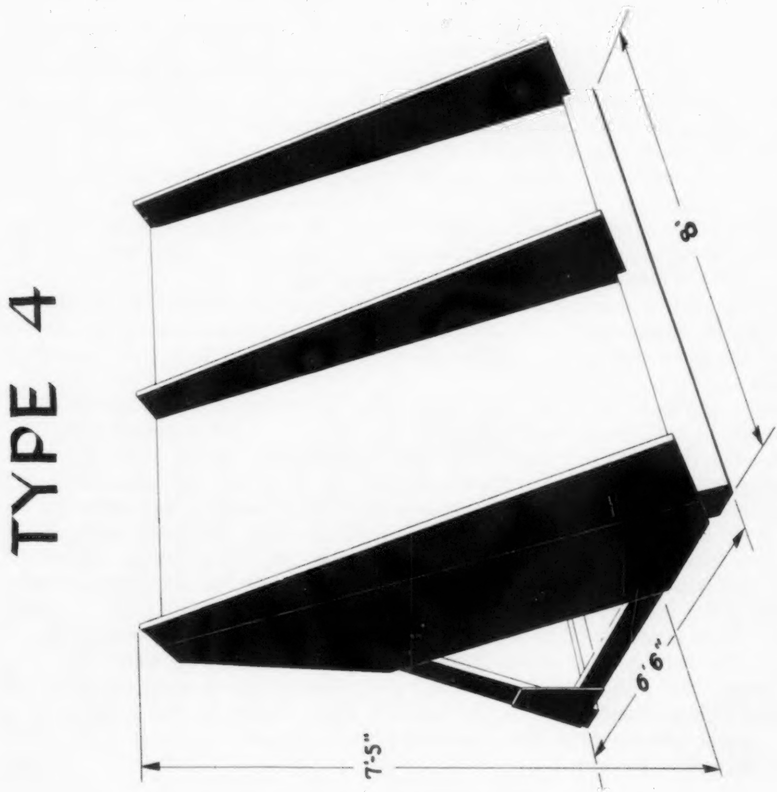


Fig. 13. Test Fence Section.

As shown in Figure 14 the terminal area was the same as used previously with the addition of the deflector fence between gate positions. The 707 prototype and a KC-135 jet tanker were spaced with a 25 foot wing tip to terminal clearance at gate positions spaced at 200 feet apart. The area was instrumented with velocity and sound pickups and the results were summarized as shown on Figure 15.

Figure 16 presents the sound levels recorded inside and outside of the terminal building. The effectiveness of the building in reducing the maximum sound level in the order of 20 db to a value of 92 db is illustrated. Also the effect of reducing the high frequency noise may be noted.

A similar illustration of the effect of the fence at the adjacent gate position is shown in Figure 17. The sound level at the adjacent airplane behind the fence was 17 db less than the sound level by the maneuvering airplane in front of the fence. The satisfactory deflection of the high frequency noise by the fence may be noted. Observers considered the use of such fences at high density terminals would permit unrestricted ground servicing and loading of passengers and taxiing of aircraft at adjacent gate positions.

Another consideration of noise in the terminal area involves the taxiing procedures utilized. Tests have been made to record the sound level produced from four J-57 engines equipped with 12 db sound suppressors during various conditions, as shown on Figure 18. Sound levels were recorded at a distance of 100 feet from the nearest operating engine.

As indicated, a reduction in sound level of about 6 to 8 decibels is achieved when turning maneuvers are accomplished by two engines on one side (case 2) rather than from one inboard engine (case 1) which would be at a relatively high power.

Also, there is a reduction in sound level in the order of 2 to 3 decibels when straight taxi is accomplished with four engines at a low power (case 3) compared to taxi with two engines at an equivalent total thrust (case 2).

The typical noise exposure from a location in front of a Terminal building is indicated on Figure 19. The top line, shown for reference, indicates the sound level from an airplane with engines at full power. The maximum point at the left shows the value when the airplane is at 200 feet from the observer and the continuation of the line illustrates the attenuation of the sound as the distance to the observer is increased.

The actual exposure of the observer outside of the terminal, however, is shown by the bottom line, which illustrates the reduction in DB when the engines are at idle. The peak in the lower curve occurs for a short duration increased power required to initiate the taxi roll. Power is then reduced to slightly above idle for taxi to the point of takeoff. There is no engine runup time at the end of the runway.

Community Considerations

There are several factors that are favorable to the operation of commercial jet transports during takeoff. It is the takeoff phase which involves the consideration of adjacent community relations as effected by the noise of an aircraft, since it is normally during this phase only that takeoff power is used. This, of course, is with the exception of ground trimming of jet engines in a maintenance area or ground and pre-takeoff runups of piston engined aircraft.

One of the characteristics of sound is that the higher frequencies are

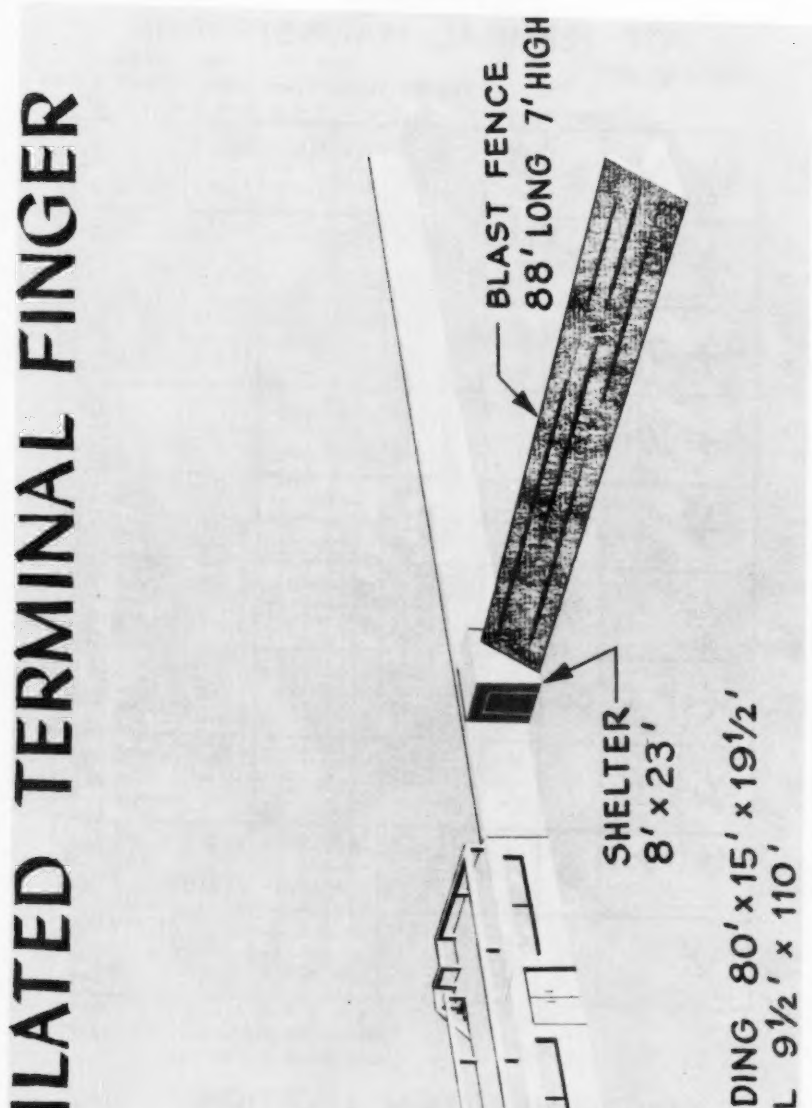


Fig. 14. Simulated Terminal Area.

BOEING
707 TERMINAL DEMONSTRATION

MARCH 18, 1957

	CONDITION		THRUST 1	THRUST 2	THRUST 3	THRUST 4	JET VELOCITY (MPH) 1	2	3	4	5	MAX. OVERALL SOUND INTENSITY (DB) A	B	C	D	E	F	G*	H*
45° NOSE-IN	1	IN	1100	1100	1100	1100	0	0	0	20	0	108	80	AMB	81	102	105	95.5	111.5
		OUT	600	600	2850	2850	35	27	20	40	0	118	90	98	98	119	105	102	125
45° NOSE-OUT	2	IN	1100	1100	1100	1100	0	45	16	0	0	116	AMB	91	88	104	96.5	97	123.5
		OUT	600	600	2850	2850	50	61	0	0	0	113	90	96	86	95	94.5	96	113.5
56° NOSE-OUT	3	IN	1100	1100	1100	1100	37	40	46	0	0	115	AMB	90	89	104	94.5	98	114.5
		OUT	1550	1550	1550	1550	50	50	32	0	0	106	88	AMB	79	93	92	925	95.5
PARALLEL PARKING	4	IN	1100	1100	1100	1100	—	—	—	—	—	115	82	AMB	74	95	91	925	108.5
		OUT	2850	2850	600	600	50	71	57	0	0	120	90	AMB	96	110	101	104	124.5
PARALLEL PARKING ADJACENT AREA	5	IN	1100	1100	1100	1100	—	—	—	—	—	93	AMB	AMB	91	99	99	96.5	103.5
		OUT	600	600	2850	2850	—	—	—	—	—	102	AMB	AMB	98	106	104	—	—
PARALLEL PARKING ADJACENT AREA	6A	IN	1100	1100	1100	1100	0	0	0	42	0	96	AMB	90	92	102	98	100	116.5
		OUT	2850	2850	600	600	0	0	56	38	39	99	83	96	99	108	100	985	116.5
PARALLEL PARKING ADJACENT AREA	6B	IN	1100	1100	1100	1100	0	0	0	37	0	94	AMB	AMB	100	108	100	925	118.5
		OUT	2850	2850	600	600	0	0	45	42	50	105	87	96	112	114	101	105	117.0
90° NOSE-IN	7	IN	1100	1100	1100	1100	—	—	—	—	—	94	AMB	AMB	95	95	90	90	109
		OUT	TOW OUT				—	—	—	—	—	—	—	—	—	—	—	—	—
TAXI BY TERMINAL	8	A	1000	1000	1000	1000	—	—	—	—	—	95	AMB	AMB	96	97	102	106.5	110.5
		B	600	2750	2750	600	—	—	—	—	—	95	AMB	AMB	95	96	103	925	90
TWO ENGINE PULL AWAY	9	IN	1300	1300	1300	1300	—	—	—	—	—	93	AMB	AMB	94	95	94.5	96.5	127
		OUT	600	4300	2200	600	0	0	0	38	0	108	95	94	114	117	111	—	—

* INTENSITIES (G & H) RECORDED ON TAPE
AMBIENT AT C = 90 db

INSTRUMENTATION LOCATION

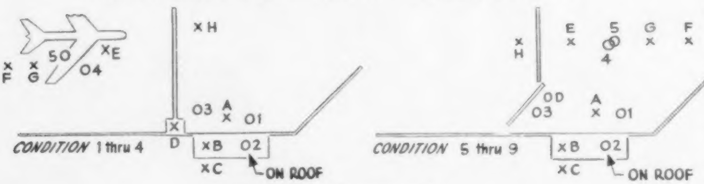


Fig. 15. Summary.

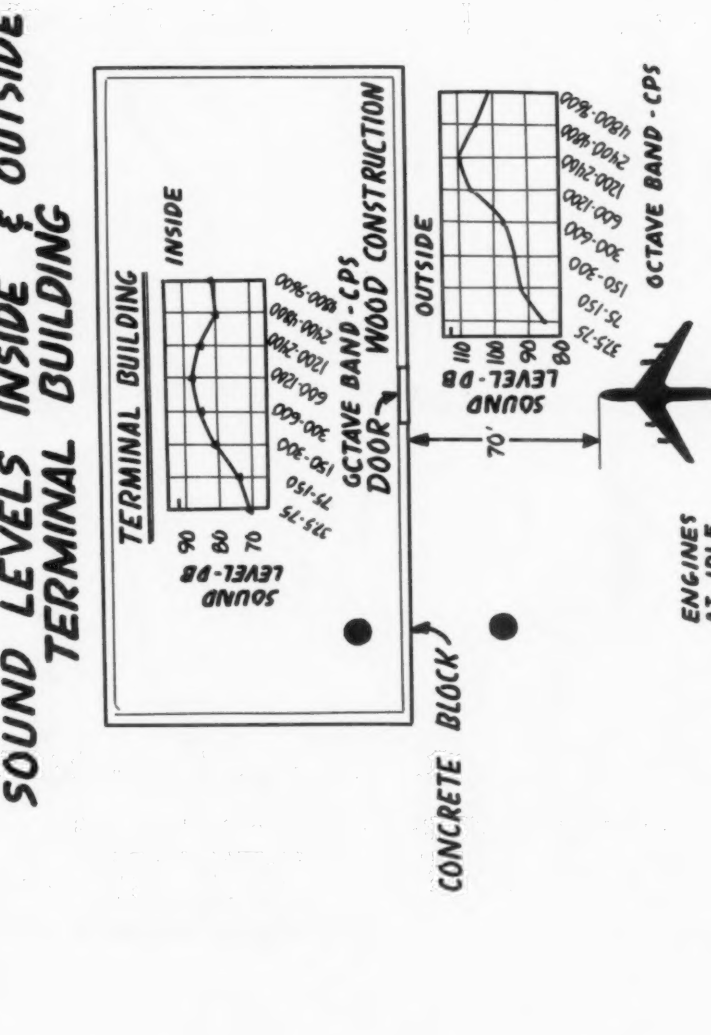


Fig. 16. Sound Level Spectrum.

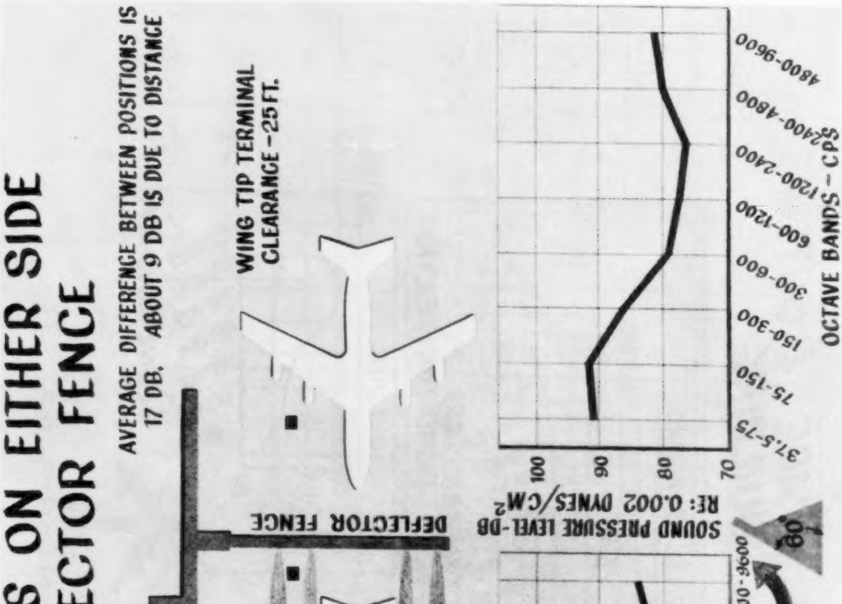


Fig. 17. Sound Level Spectrum.

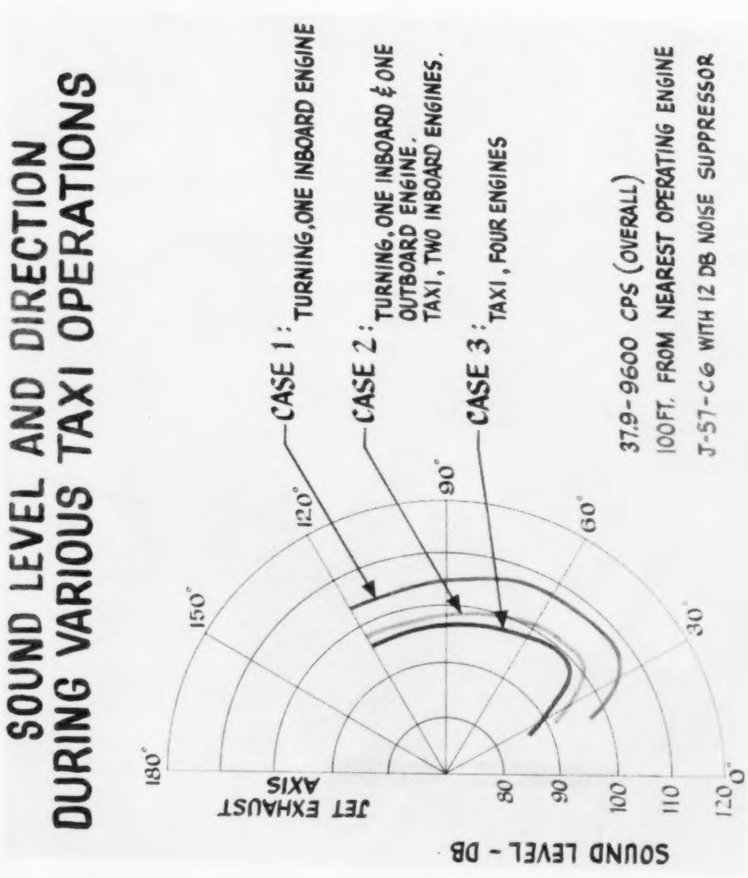


Fig. 18. Taxi Operation Sound Levels

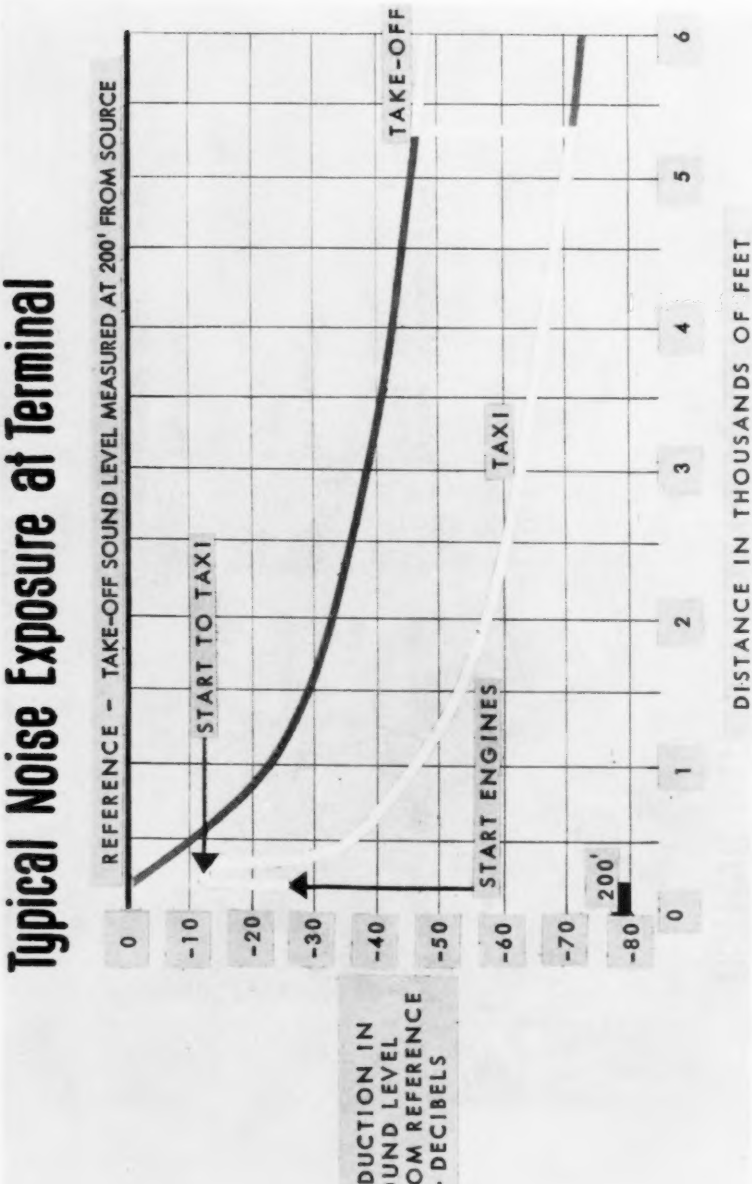


Fig. 19. Typical Noise Exposure at Terminal.

rapidly attenuated with distance as shown on Figure 20. This characteristic is employed to advantage in current suppressor designs which attenuate low and medium frequencies of the jet exhaust by the greatest amount.

Measurements of the takeoff sound of the 707 prototype with experimental suppressors and the takeoff sound of the DC-7 are illustrated on Figure 21. The relative climb paths are for the airplanes at maximum gross weight, sea level standard conditions and the plan view shows the area bounded by a sound intensity of 90 decibels at the corresponding climb paths illustrated.

The 707 climb operation is shown for three different procedures. The maximum climb path of the 707 illustrated by condition No. 2, is steeper than the climb path of the DC-7 and the area bounded by the 90 decibel sound intensity for the 707 is three percent more than the corresponding area for the DC-7.

Condition No. 1, illustrates a 707 climb-out during which the airplane accelerates as it climbs. The area covered during this procedure for the 707 is 8% greater than the DC-7 area. For condition No. 3, the 707 climbs to 1000 feet, accelerates and then flies level at reduced power until it is beyond congested communities. The area bounded by the 707 90 decibel sound contour during this procedure is only 61% of the area for the DC-7. Figure 22 illustrates a similar comparison of the 707 and DC-7 climb paths and 90 decibel sound contours at lighter gross weights. The area for the 707 at maximum climbout is 22% greater than the DC-7 area at maximum climbout and 33% greater during the normal accelerating climb procedure. However, for an accelerate and level flight procedure at reduced power the 707, 90 decibel sound contour, covers only 76% of the area covered by the DC-7.

Much of the domestic Boeing 707 Jet Stratoliner operation will be at less than maximum gross weight and probably a more reasonable comparison for any specific trip would be to compare the areas for the DC-7 at 125,000 lb. and the 707 at 202,000 lb. For such a comparison, the areas covered by the 707, 90 decibel sound contours, are less than the DC-7 area for all 707 climb procedures, as follows:

Condition 1.	97%
Condition 2.	82%
Condition 3.	55%

CONCLUSION

The Boeing Airplane Company recognized the desirability of developing civil jet transport sound suppression devices early in the 707 program. Although initial results were not very promising, suppressor devices were later developed that achieved the amount of suppression that had been guaranteed to our customers. Continued effort has resulted in the development of devices that will suppress the sound by an amount considerably more than that guaranteed. The 707 will be fitted, this summer, with four sound suppressor devices that are considered to be the prototype model of the production units.

Many airport operators and airline representatives, who have observed a 707 terminal demonstration consider the civil jet transports will operate in close proximity to terminals under normal taxi operations with no difficulty. It is recognized that it will be desirable to segregate the passengers, visitors and terminal personnel from the ramp areas by means of buildings and walls, just as it is desirable with present aircraft and done in modern terminal

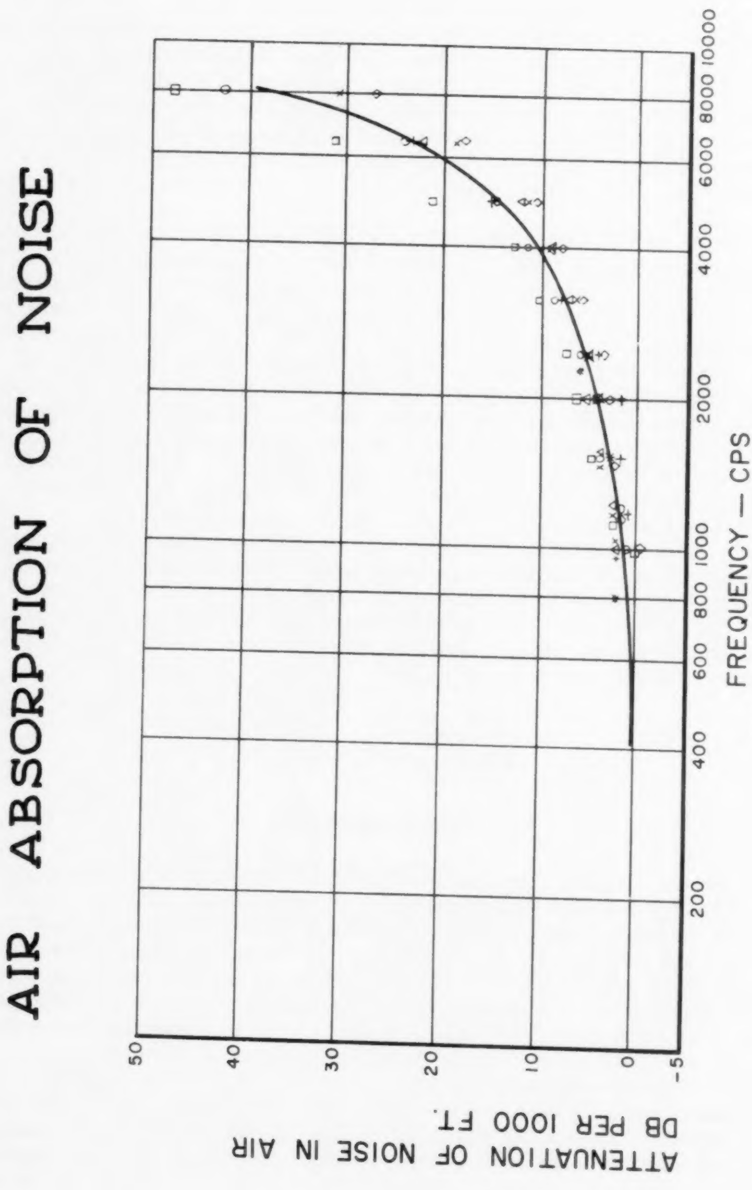


Fig. 20. Frequency Attenuation.

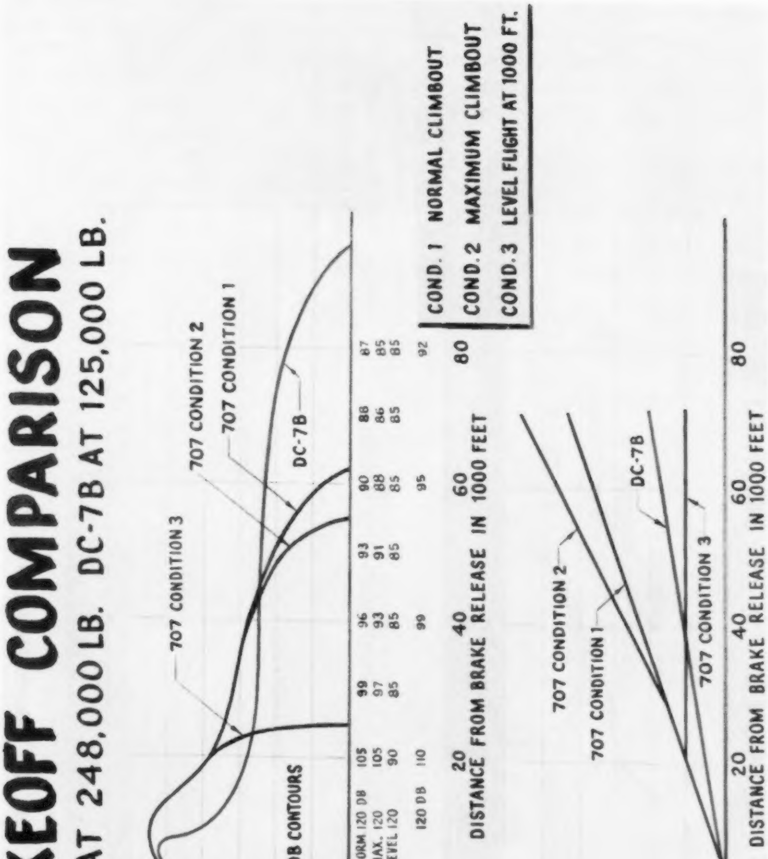


Fig. 21. Takeoff Noise 707 and DC-7 (Heavy Gross Wt.).

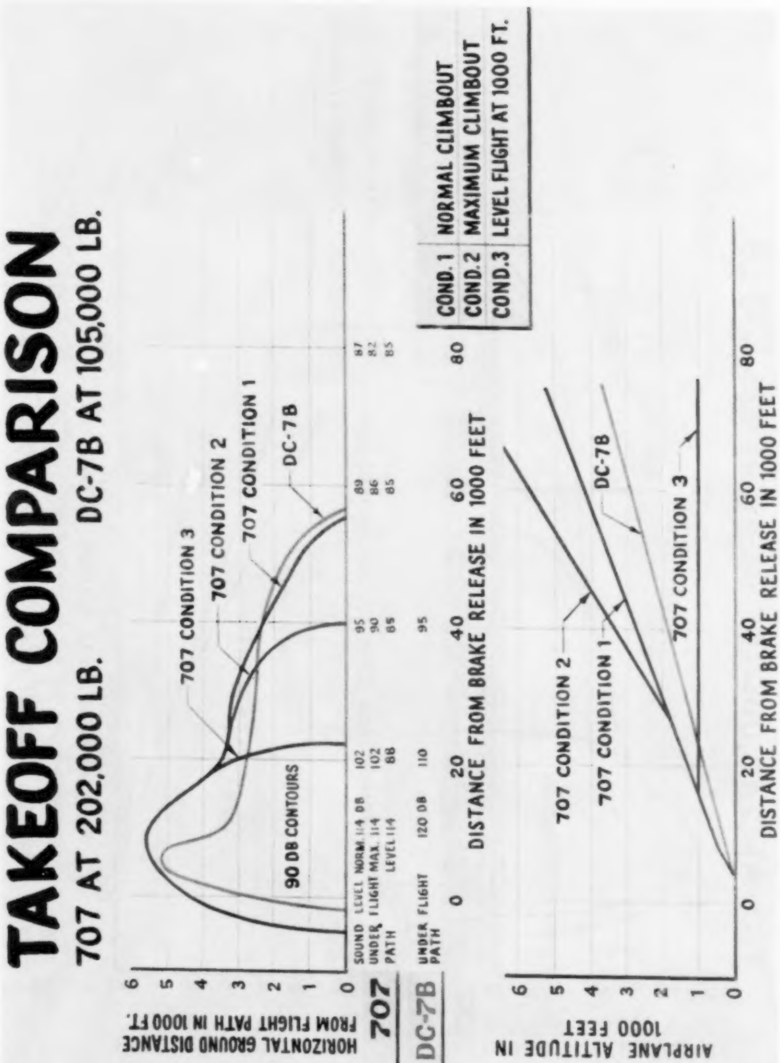


Fig. 22. Takeoff Noise 707 and DC-7 (Light Gross Wt.).

design. Also, deflector fences may be used between gate positions at high density terminals to permit unrestricted operation at adjacent gates. With an enclosed terminal building, underground refueling facilities, improved airplane baggage handling systems, etc., many of the observers at the 707 demonstrations expressed the opinion that jet transport terminal handling operations would be a definite improvement over present operations.

With the use of effective suppressors and the best climbout procedures for each locality and trip operation, the civil jet transports are expected to operate with no more annoyance to airport neighbors than some of the present large civil transports.

I am sure all of the manufacturers of civil jet transports are accomplishing sound suppression development programs similar to that at Boeing. But, the complete success of the operation of commercial jet transports at terminals and in communities will only be achieved if the airports are planned and aircraft operated to take advantage of their characteristics and capabilities.

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

OPERATIONAL CHARACTERISTICS OF THE DOUGLAS DC-8[a]

J. B. Edwards[1]
(Proc. Paper 1470)

SYNOPSIS

This paper discusses planning of aircraft for the jet age, gives a general description of the Douglas DC-8, and describes the operational capabilities of this aircraft on and around air terminals. Also presented are some innovations intended to protect jet engines from ingestion damage and improve operational training.

It is a privilege to be able to describe the DC-8, and to outline how it fits into the overall pattern of air transportation.

The intimation that there is an overall pattern may alarm those who have grown accustomed to confusion, so maybe we should take a quick look at the growth of the air-transport business and the emerging pattern.

During the past twenty years, traffic has multiplied nearly one hundred times; speeds have increased from 180 to 600 miles per hour; aircraft costs have climbed from one hundred thousand to five million dollars per copy; first class passenger fares have reduced from 6 cents to less than 3 cents per mile at equal dollar value, and the number of aircraft in U.S. transport operation has gone from 290 to 1250.

It has taken time to recognize the inexorable quality of this growth. For years the leaders of our business, who by and large are the founders of air transportation, have looked at forecasts, usually 5 year extensions which showed a declining rate of growth from that which appeared at the moment of the forecast. After several occasions in which the 5 year forecast was exceeded within about 2 years, they realized that the growth of air transportation was attributable to something more permanent than the technical improvements in aircraft and operations being introduced from year to year.

Note: Discussion open until May 1, 1958. Paper 1470 is part of the copyrighted Journal of the Air Transport Division of the American Society of Civil Engineers, Vol. 83, No. AT 2, December, 1957.

a. Paper prepared for presentation at Jet Age Airport Conference, New York, N. Y., May, 1957.

1. Asst. to Chief Engr., Douglas Aircraft Co., Inc., Santa Monica, California.

Appreciation of this growth tendency, however, was not a factor of general public and official recognition, until the appearance of the rather dramatic publicity and press comments which were occasioned by the order of jet transports. At this point, with speeds doubling, aircraft prices doubling, and the major airlines of the world laying their dollars on the line, there came a sudden realization in the general business world that air transportation was out of the infant stage. The results of surveys by Government agencies, financial groups, and other interested parties substantiated the validity of a continued high rate of growth and led to the formation of planning activities in both government and industry of a far more substantial character than the modest efforts in this field prior to 1955. While much of this planning is directed toward airways control and air-terminal expansion, the magnitude of performance and capability improvements made possible by jet power - as well as the tremendous dollar sums invested in airline fleet re-equipment have called for a new look at world route structures and a study of idealized equipment to suit the major traffic patterns.

In the planning of aircraft types, there is a natural variation between the ideal and the practical which must be resolved and compromised in favor of operational economics. For example, there is a theoretically ideal airplane design for every city pair, whether New York and Boston - with 2200 passengers a day, or Dallas to Austin with 90 passengers daily traveling the same distance of 184 miles. New York and Chicago - with 2500 passengers a day at 724 miles, or, at the same distance, Reno to Las Vegas with 30 passengers. New York to Los Angeles with 1300 passengers a day, or Seattle to Washington with 60 passengers traveling about 2500 miles.

Manufacturers, however, do not sell airplanes to city pairs, but to airlines, and the number of airlines who enjoy the possible benefit of operating a single city pair make a pretty small dent in the air-transport business. Consequently, weighted averages are used to determine a minimum number of basic types so that the manufacturers and operators of air equipment can operate most efficiently. These types have been resolved into long range, medium range, and short range. Payload varies in the same way, with the largest number of passengers in the long-range type. All new designs have one thing in common, the turbine engine, which with or without propeller shows substantial gains in speed, comfort and economy over the piston-engined aircraft. There remains, however, considerable argument as to the choice of pure jet or prop- jet in these areas of use, although the long-range-design choice seems well resolved by the preponderance of pure jet equipment ordered for such routes.

The DC-8 was designed for the medium to long range type of operation typified by domestic North-South, trans-continental, and trans-oceanic service. Its configuration is shown in Figure 1. Its fuselage holds any combination of passengers from 118 first class to 179 third class, and a cargo volume of 1415 cu. ft. which may be loaded to a maximum weight of 21,200 pounds with local densities as high as twenty pounds per cu. ft. The wing is a three spar box of 2758 sq. ft. which holds up to 140,500 pounds of fuel. It supports 4 engines which may be P&W J-75, P&W J-57, or Rolls Royce Conway. The engines are located in pods in the interest of safety, noise, maintenance, and interchangeability of engine types.

Both wing and tail are swept back to a degree appropriate to the drag associated with the design speed.

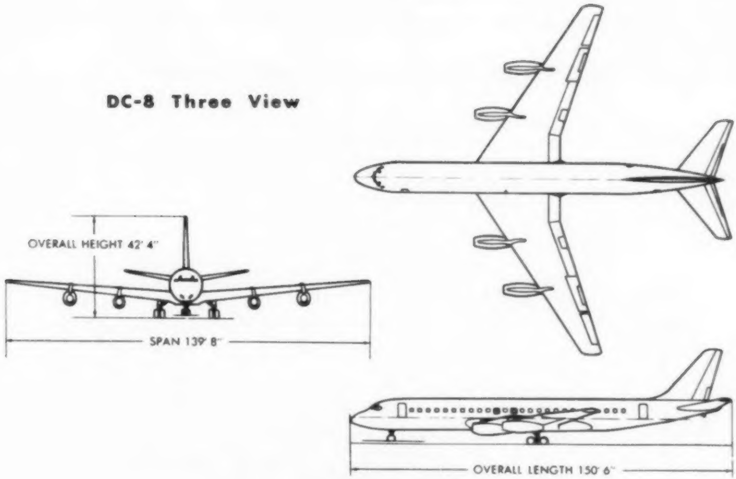


Fig. 1.

The landing gear is of the double bogie type - with 4 main wheels on each side and a dual nose wheel. The use of so many wheels helps in two ways - it reduces the runway bearing strength required, and simplifies the problem of stowage when wheels are retracted.

In developing this airplane, we have greatly expanded our interest in, and study of, operational problems, both in flight and on the ground, as compared to the purely theoretical design of a flying machine.

In flight operations, while the DC-8 will cruise at between 550 and 600 miles per hour, it must be able to join the parade of other transport types in the holding and landing traffic control pattern. The selection of wing and flap used give speeds at average landing weights for downwind leg of 155 knots, base leg 140, final approach 128 and runway contact 118 - all with a substantial margin above stall speeds.

Some idea of the operational capabilities of the DC-8 at various ranges are shown in Figure 2.

Performance

Block Distance	(n mi)	500	1,000	2,000	3,000	3,380
Payload	(lb)	35,930	35,930	35,930	35,930	35,930
Takeoff Weight	(lb)	202,800	214,870	244,220	275,140	287,500
Takeoff Distance (SL)	(ft)	4,400	4,710	6,150	7,910	8,750
Landing Weight	(lb)	182,100	182,100	182,100	182,100	182,100
Landing Distance (SL)	(ft)	6,350	6,350	6,350	6,350	6,350
Block Speed	(kt)	382	428	458	469	472
Cruise Speed	(kt)	499	493	494	494	494
Fuel Burned	(lb)	20,700	32,770	62,120	93,040	105,400
Cruise Altitude	(ft)	25,000	30,000	30,000	30,000	30,000
Average Rate of Climb to Cruise Altitude	(ft/min)	2,780	2,380	1,995	1,615	1,490
All Engine Take-Off Rate of Climb at Sea Level	(ft/min)	2,625	2,475	2,160	1,870	1,760

Fig. 2.

As we move on to the ground handling of the DC-8, it may be mutually helpful to follow a sequence of events beginning with landing and ending with take-off.

Fig. 3 shows what to expect in the way of landing distances.

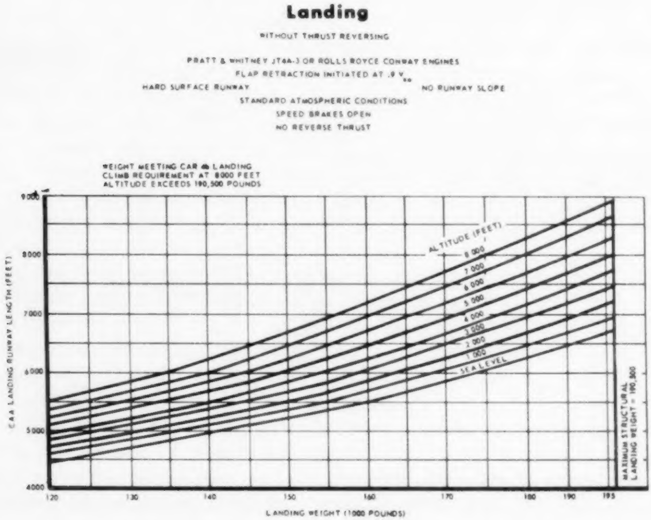


Fig. 3.

As the peak loads at the airports increase with traffic, many of you are exploring methods to reduce runway occupancy time. On the assumption that high speed turnoffs will come into use, we have plotted (Figure 4) the structural design of the DC-8 gear along with a possible passenger comfort limit for your information.

As the airplane taxis in to the passenger ramp, it is capable of making tight turns without tire scrubbing because the aft pair of wheels of the bogie gear are castered. In a 180° turn, the wing tip will swing on a radius of about 90 feet, the tail clearance will be inside this circle by 1 foot, and the width of the runway used for the wheels will be about 87 ft.

With the airplane brought to a halt and power off, studies indicate a complete turnaround may be accomplished in 30 minutes. The time and activity breakdown is shown in Figure 5.

This is the result of studies made by the Ground Equipment group, who surveyed current operational practices at several airports, and then ran experimental tests with the DC-8 mockup. The entire servicing operation has been expedited by the inclusion of two passenger doors, two buffet service doors, four cargo compartment doors and underwing pressure refueling. Fueling may be done through 4 connections at the rate of 1200 gallons per minute. The cargo doors are 36 in. x 44 in., the buffet service doors are 37-3/8 in. x 64 in., and the passenger doors are 34-1/2 in. x 72 in.

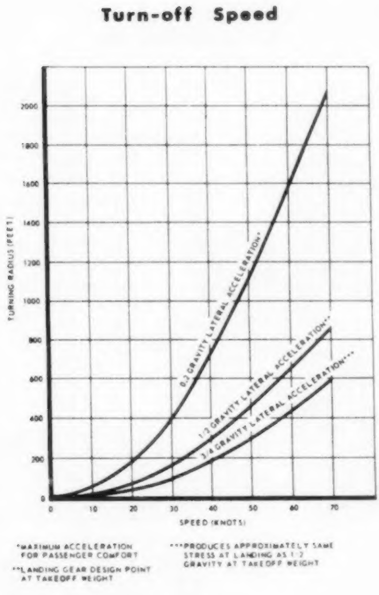

Turn-off Speed
TURNING RADIUS (FEET)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0 10 20 30 40 50 60 70
SPEED (KNOTS)
0.3 GRAVITY LATERAL ACCELERATION*
1/2 GRAVITY LATERAL ACCELERATION**
3/4 GRAVITY LATERAL ACCELERATION***
*MAXIMUM ACCELERATION FOR PASSENGER COMFORT
**LANDING GEAR DESIGN POINT AT TAKEOFF WEIGHT
***PRODUCES APPROXIMATELY SAME STRESS AT LANDING AS 1/2 GRAVITY AT TAKEOFF WEIGHT

Fig. 4.

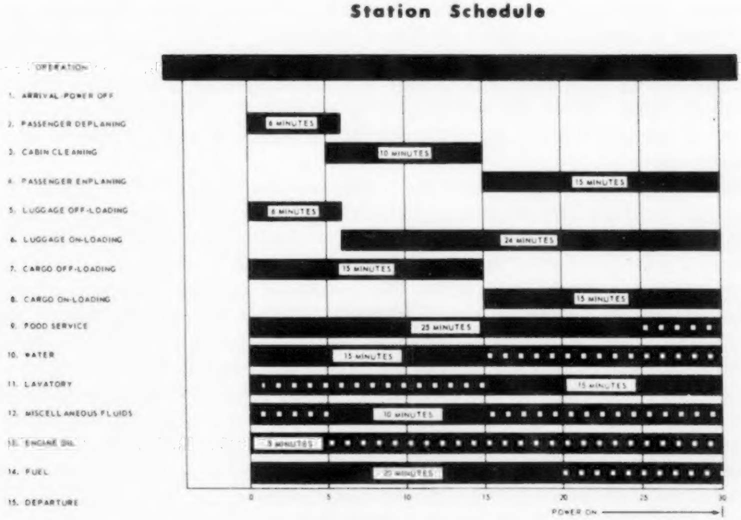
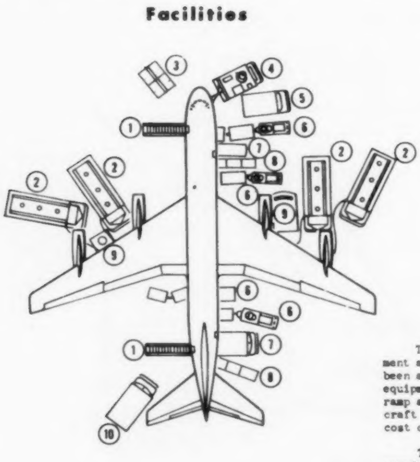

Station Schedule
OPERATION
1. ARRIVAL-POWER OFF
2. PASSENGER DEPLANING
3. CABIN CLEANING
4. PASSENGER ENPLANING
5. LUGGAGE OFF-LOADING
6. LUGGAGE ON-LOADING
7. CARGO OFF-LOADING
8. CARGO ON-LOADING
9. FOOD SERVICE
10. WATER
11. LAVATORY
12. MISCELLANEOUS FLUIDS
13. ENGINE OIL
14. FUEL
15. DEPARTURE
6 MINUTES
10 MINUTES
15 MINUTES
6 MINUTES
24 MINUTES
15 MINUTES
15 MINUTES
25 MINUTES
15 MINUTES
15 MINUTES
10 MINUTES
3 MINUTES
20 MINUTES
0 5 10 15 20 25 30
POWER ON

Fig. 5.

The ground equipment required to effectively service this class of airplane at turnaround stations should be given careful consideration. Figure 6 and Figure 7 indicate how bad the situation could be - or how good.



The concentration of portable servicing equipment around an airplane at a gate position has always been a problem with current aircraft. The cost of the equipment and the space it occupies when parked on the ramp are steadily mounting. Structural repairs to aircraft damaged by collision with mobile equipment has cost one airline $1,000,000 annually.

This illustration shows the jet transport with approximately nineteen pieces of equipment surrounding it. With present methods, this many pieces of equipment would be needed to provide the simultaneous servicing which is essential to the shortest possible enroute and turnaround stages.

Fig. 6.

Engine starting is accomplished by supply pressure air to a starter turbine which is geared through a clutch to the engine shaft. The pressure air may be supplied from a ground system or from an external starter cart to start any one or all 4 engines. A self-contained system is also provided to start one engine. After any one engine is started, the remainder may be started by bleed pressure from the operating engine through the aircraft pneumatic system.

Engine starting and taxi from the ramp, as compared to a tow-away operation, has been the subject of considerable discussion and testing because of the noise problem. While the writer feels that this is a matter to be decided jointly between the airport operators and the airlines, and may vary according to specific location, the results of a recent test conducted at the San Francisco Terminal are of interest. During this test, some 150 observers representing airlines, airports, consultants, etc., were stationed at 15 positions on the ramp and inside the terminal. In addition, over 80 general-public visitors and passengers were canvassed in the waiting room, coffee shop, and passenger loading fingers. Of this latter group some 27% had, so to speak, been around jet aircraft, and the remaining 73% were unacquainted with them.

This group replied to three questions as follows:

1. What part of the jet noise bothers you most?

   12% - rumbling exhaust

   88% - high pitched whine

Fig. 7.

2. When does the noise seem worst?
   46% - when plane comes toward me
   21% - when plane turns in front of me
   25% - when plane is going away
   8% - didn't notice
3. In your opinion, should engines be stopped far away from ramp, and planes towed to passenger ramp?
   22-1/2% - yes
   77-1/2% - no

From this it may be concluded that with glassed-in terminal and glassed-in passenger fingers, which is the case at San Francisco, the protection will be adequate for taxi to ramp operation.

The experts on the ramp, incidentally, were in good agreement that field personnel required to be in exposed areas during start and taxi should use ear-protective devices, and that the use of blast fences would contribute to the comfort of loading and unloading passengers and field personnel. It is interesting that several observers thought this would also be a good idea with our present aircraft.

In the period after engine starting, and during taxi and the start of take-off there is a critical possibility of engine damage by the intake acting as a vacuum cleaner for rocks and debris which might be on the strips. The funnel from the ground to the intake exists only if a vortex or little whirlwind is induced by ground winds. While this obviously doesn't happen a large part of the time, it is the cause, according to the Air Force, of almost 50% of the

premature damage and consequent replacement of engines. With jet engines costing roughly a quarter of a million dollars each, it was apparent that some protective device would be highly desirable.

An immediately obvious answer was to use a screen over the intake, but this offered additional problems of snow and ice blockage - interference with inlet air, and a retraction operation during the take-off run. After considerable study of the problem we hit on the idea of eliminating the vortex by the device shown in Figure 8. This is a small, high-speed jet of air bled from the compressor section which, by a wiping action on the ground, completely prevents vortex formation. Although this device reduces the thrust only 1/4 of 1 percent, the jet is automatically turned off when the aircraft speed goes above 40 miles per hour. Both Douglas and the NACA have run sufficient tests on this device to believe it will greatly reduce the common intake-damage problem.

Since the aircraft is in its heaviest state at take-off, we should examine runway and taxi way strength requirements at take-off weights. In Figs. 9 and 10 we see the pavement thickness in either concrete or asphalt required by the DC-8 at a variety of weights. As a matter of interest it should be noted that the present large transports with dual wheels require almost identical thicknesses at their take-off weights.

Take-off runway length is established by gross weight and varies according to field altitude, field temperature, slope and wind. The exact requirement has to be established at each flight of a given type airplane because of the many variations.

A generalized curve is shown in Fig. 11 to illustrate the take-off field length required for the DC-8 at 100% payload with range, field altitude, and temperature as variables.

Aero - Screen

Experience shows that much present-day jet engine damage is due to pebbles or metallic parts entering the engine. A large portion of these are sucked up by a vortex (shown in sketch) which sometimes forms in front of the inlet. The Aerodynamic Screen, a device developed by Douglas Aircraft Company for the DC-8, prevents formation of this vortex and thus eliminates this particular source of foreign material entry. This device consists of a small downward-directed jet of air below the engine inlet.

It is essential, however, that the ramp, taxi-ways, run-up areas and runways be clean of debris. A large portion of the jet engine damage due to foreign object ingestion is due to debris blown into the engines by other aircraft or field wind conditions.

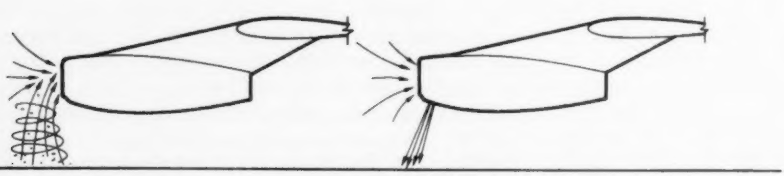
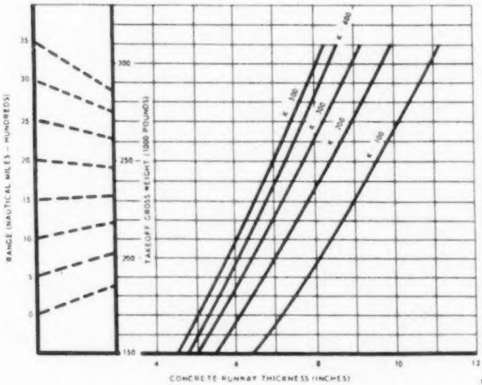


Fig. 8.

Runway

RIGID (CONCRETE) PAVEMENT



CURVES ARE BASED ON
A. U 700 POUNDS PER SQUARE INCH AT 28 DAYS.
B. STRENGTH INCREASE WITH AGE 14 PERCENT
C. DESIGN SAFETY FACTOR 1.5

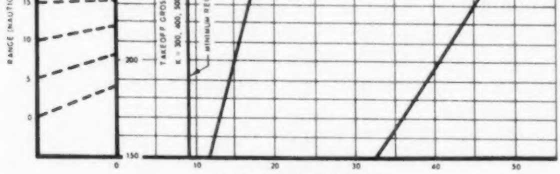
U ULTIMATE STRUCTUAL STRENGTH

THE RIGID (CONCRETE) PAVEMENT REQUIREMENTS ARE BASED ON THE METHODS ACCEPTED BY THE UNITED STATES CIVIL AERONAUTICAL ADMINISTRATION, THE UNITED STATES CORPS OF ENGINEERS, AND THE PORTLAND CEMENT ASSOCIATION.

Fig. 9.

Runway

FLEXIBLE (ASPHALT) PAVEMENT



THE FLEXIBLE (ASPHALT) PAVEMENT REQUIREMENTS ARE BASED ON THE METHODS USED BY THE UNITED STATES CORPS OF ENGINEERS, FLEXIBLE PAVEMENT BRANCH.

NOTE

1. LAYERS COMPOSING A PAVEMENT WILL VARY IN NUMBER AND INDIVIDUAL THICKNESS, DEPENDING ON MATERIAL USED.
2. TO GET TAXIWAY THICKNESS, INCREASE RUNWAY THICKNESS 11 PERCENT.

TYPICAL RUNWAY CONSTRUCTION

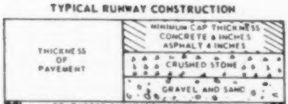


Fig. 10.

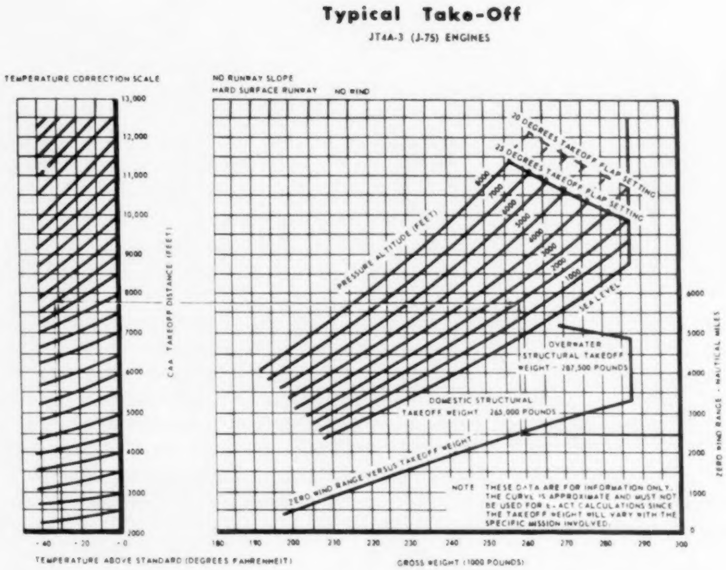


Fig. 11.

Since the worst numbers on this chart obviously go above 13,000 feet, and since we have all been exposed to conversation about the 15,000-foot runway requirements of the new jet transports - let's look at some actual situations, and see where we need really long runways.

First of all, we must be faced with a combination of maximum range, high altitude and high temperature to get to the big numbers. There are a few foreign locations where these things exist. Johannesburg, Africa, for instance, has a field altitude of 5555 feet. Under C.A.A. rules, the maximum weight of the DC-8 out of Johannesburg would require 11,400 feet on a standard day and 13,900 on a 41° hot day. Bogota, Colombia is at a height of 7274 feet. A maximum run from this city would require a runway length of 11,850 ft. - standard day, and 14,500 ft. on a 41° hot day. Mexico City which is 7347 ft. altitude would require at maximum weights 11,900 ft. on a standard day, and 14,600 ft. on a 41° hot day.

In the United States, we don't have cities that combine such high altitudes with such extreme temperatures. Denver for instance, at an altitude of 5331 feet, is the highest major airport in the country. A direct flight in a DC-8 from Denver to Honolulu would require around 11,000 ft. of runway on a standard day, and about 13,500 ft. on a 41° hot day. Operations out of Chicago, at 657 ft. elevation, to Europe direct require 9,050 ft. of runway on a standard day, and 10,200 ft. on a 41° hot day.

Considering these extreme cases, it should be evident that most airports in the U.S. and in the world which expect to handle the big jets will be in the 7,000 to 9,000 ft. bracket.

In closing - the writer would like to mention one more area in which we are attempting to alleviate a typical combination of problems.

Pilot training is a very necessary thing to the safety and proper operational use of today's complex aircraft. The hazards of training in flight affect the manufacturer, the operator, and the airport community. To reduce this type of flying to a minimum, a DC-8 simulator is being built to our specifications by Link Aviation and will be in service prior to our first airplane flight. Having a simulator in operation prior to first flight is an innovation in the air-transport business, and will permit our engineers and pilots to not only completely study systems operations, but establish the desired flight control forces. Another connected development (Figure 12) is the Douglas-designed Telerama runway simulator. This device permits the pilot to perform an airport check out, as the field relief map may be made to duplicate any desired location. Such an instrument will save large amounts of time and money and contribute to the safety of normal passenger operations as airway and airport congestion continues to increase.

Our studies of operational problems are being carried forward at full force, and we welcome the opportunity to help airport engineers and consultants in their preparations for the jet-age.

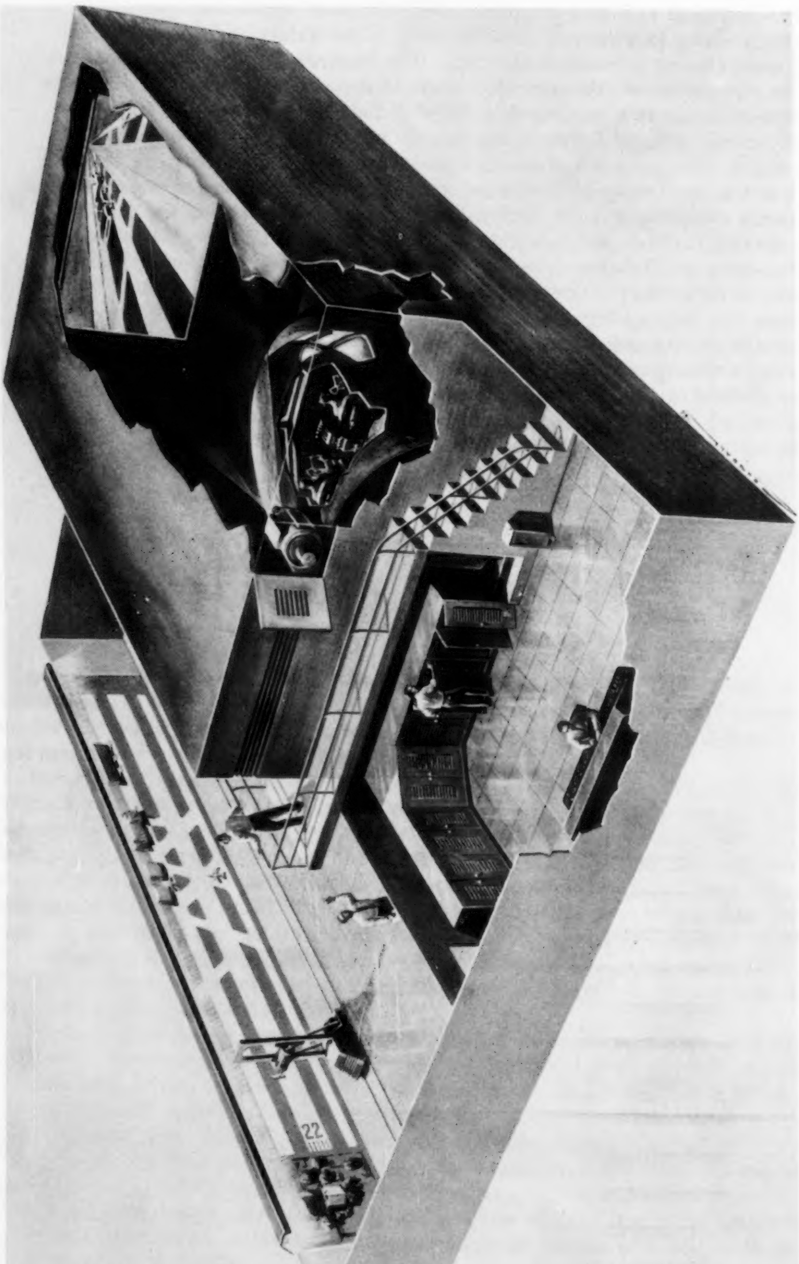


Fig. 12.

Paper 1471 December, 1957 AT 2

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

CONVAIR 880 AIRPORT OPERATIONS[a]

A. D. Riedler[1]
(Proc. Paper 1471)

SYNOPSIS

This paper describes the forthcoming Convair 880 jet transport due for airline operation in 1960. The operation of the 880 at the air terminal, and a summary statement on ground service is presented. The text and illustrations detail the 880 dimensions, interior arrangements, range, speed, payload, weight, and power plants.

INTRODUCTION

The Convair 880 jet transport is specifically tailored to the short and medium range market. However, it makes a satisfactory longer range transport as well. The 880 will enter airline operations in 1960 with TWA, followed by Delta and Transcontinental S. A. Airlines.

Primary Dimensions of the Airplane

The maximum span is $120^{\underline{0}}$ and its fuselage length $124^{\underline{2}}$. Figure 1. Height of the vertical fin is $36^{\underline{0}}$, which should cause little difficulty when hangaring. The wing area is 2000 sq. ft., not including the trailing-edge "plug" at the side of the body. The 880 is similar in appearance to other American jet transports, yet is distinguished by:

1. Trailing-edge "plug" at the side of the body
2. Slightly sharper nose
3. Very low ground position
4. The air inlets on the bottom of the fuselage, below the wing, for the

Note: Discussion open until May 1, 1958. Paper 1471 is part of the copyrighted Journal of the Air Transport Division of the American Society of Civil Engineers, Vol. 83, No. AT 2, December, 1957.

a. Paper prepared for presentation at Jet Age Airport Conference, New York, N. Y., May 16, 1957.

1. Design Specialist, Convair Div., General Dynamics Corp., San Diego, Calif.

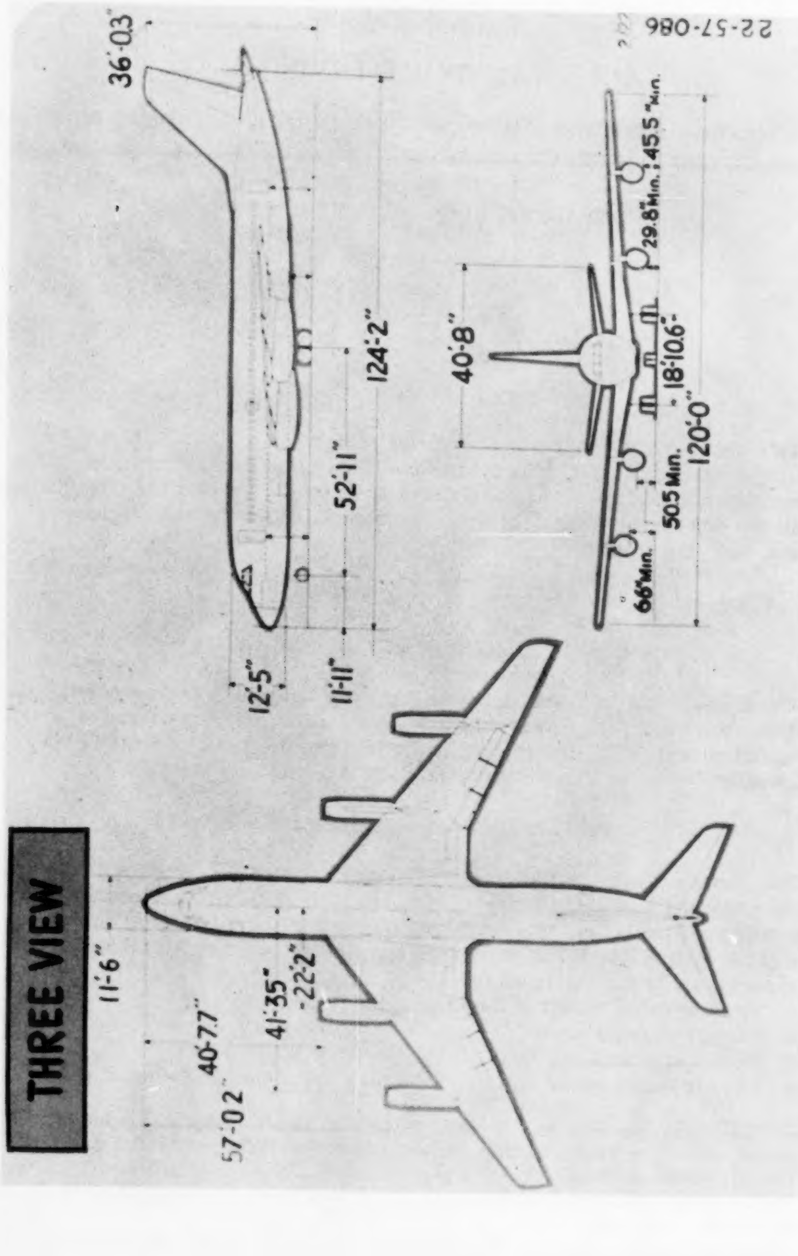

THREE VIEW
36'0.3"
124'2"
52'11"
12'5"
11'11"
40'8"
18'10.6"
120'0"
50.5 Min.
66" Min.
29.8" Min.
45.5" Min.
11'6"
40'7.7"
57'0.2"
41'3.5"
22'2"
22-57-086

Figure 1.

air-conditioning system.

5. There will be a "back-bone" fairing on the top of the fuselage which will serve to cover several antennae. (Not shown.)

Design Gross Weights of the 880

1. Maximum take-off gross weight of 178,500 lb.
2. Maximum landing gross weight of 123,500 lb., although 130,000 lb. is available with an addition of 65 lb. in the wheels and brakes.
3. Maximum zero fuel weight of 113,000 lb.

The basic operating weight is approximately 84,000 lb., depending upon the particular accommodations. The payload of the 880 consists of around 21,700 lb. in a first class, 4 abreast, 84 passenger version including a 4-person club lounge. Arrangements for coach or mixed coach—first class versions are available.

General Arrangement

Figure 2 shows two different arrangements: one a straight coach arrangement with 109 passengers; the other a typical mixed coach. The forward portion of the cabin has 40 first class passengers, including a 12-place club area, and 54 coach passengers. Other combinations are available simply by relocating a coat-space divider into another of the 5 positions.

Interior Dimensions (Figure 3)

The fuselage cross-section has been sized so as to provide 5 comfortable coach seats of the same size as today's 440. With 4 luxurious first-class seats there still remains a spacious 28 in. aisle. Convair believes there is a distinct advantage in having a 4-abreast arrangement, first class. (Figure 3.)

The area below the floor has been designed so as to give easy access to the 850 cu. ft. available for baggage and cargo. At 10 lb. per cu. ft. this gives 8500 lb. for baggage and cargo.

Power Package

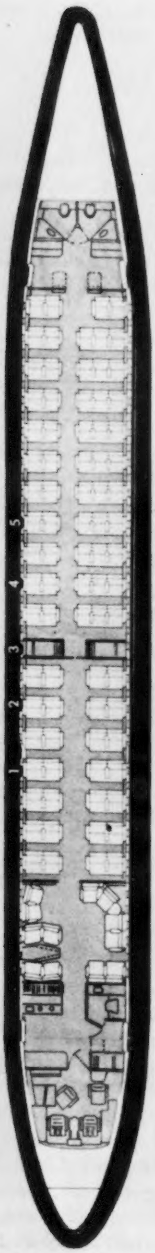
The Convair 880 utilizes 4 General Electric CJ-805 turbojet engines. The CJ-805 is the commercial version of the J-79 engine which is currently used in the Convair B-58 "Hustler" Supersonic Bomber, the Lockheed F-104 Starfighter, and others of the latest "hot-shot" military aircraft.

Although the 880 has been specifically tailored to the short and medium ranges, it proves to be a satisfactory transcontinental airplane as well. This is an important byproduct of medium range turbojet transport design. First, a large wing area is necessary to keep landing distances short for the short range field lengths. Then, with the Convair developed integral fuel tanks, it costs very little to take advantage of the full wing volume. Now this fuel is adequate for the cross-country trip, if the allowable gross weight is high enough to utilize the fuel. If the airplane is designed to fly at 600 mph, the cruise thrust is accompanied by a take-off thrust adequate to do the job. It

22-5 -056 2/22

GENERAL ARRANGEMENT

MIXED COACH



SEATING CAPACITY

SEATING ARRANGEMENT AND DIVIDER LOCATION	STANDARD SEATS	COACH SEATS	CLUB AREA	TOTAL PASSENGERS
MIXED 1	12	74	12	98
MIXED 2	20	64	12	96
MIXED 3	28	54	12	94
MIXED 4	36	44	12	92
MIXED 5	44	34	12	90

COACH

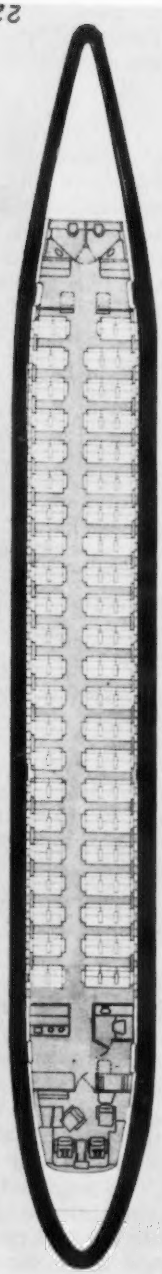


Figure 2.

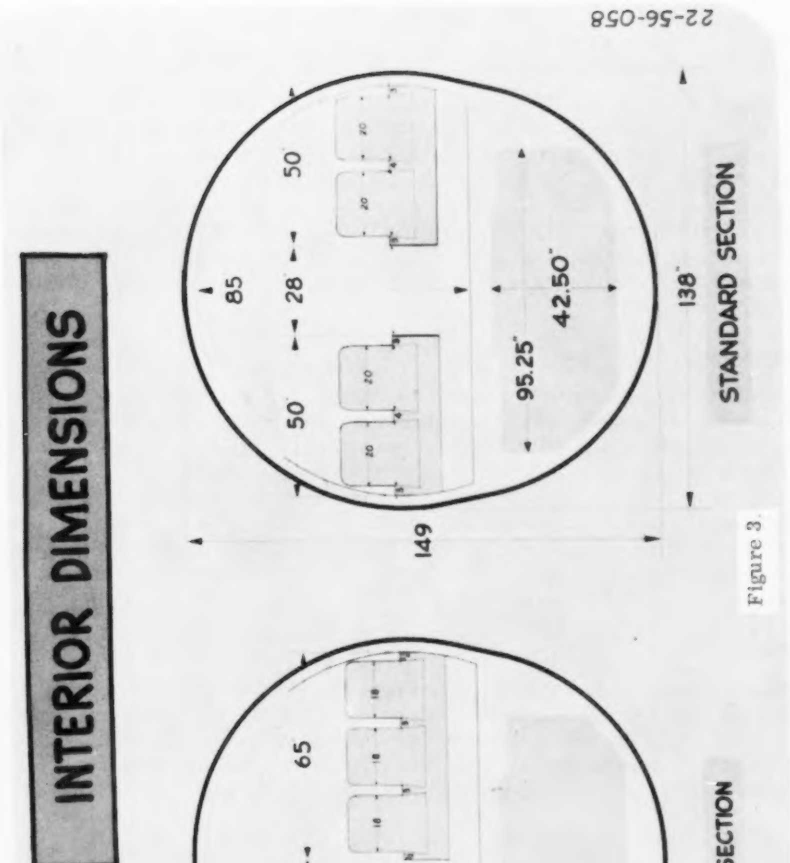

INTERIOR DIMENSIONS
COACH SECTION
STANDARD SECTION
44"
19"
65
50"
28"
85
50"
149
138"
95.25"
42.50"
22-56-058

Figure 3.

is one of the conveniences of nature. Increasing gross weight by only adding fuel in the wings (as a relieving load) adds very little structure.

Performance of the 880

Payload vs. Range

Figure 4 shows that the full coach payload of 26,320 lb. may be carried a full 2600 n. mi., or transcontinental, while still maintaining quite adequate fuel reserves of 16,000 lb., good for over 2 hours of holding at 15,000 ft. At that range the airplane is limited over a small range by its maximum allowable gross weight of 178,500 lb. It then gains range by trading payload for fuel until it too reaches its maximum of 70,000 lb. or 10,770 gal. Thus the full first class payload of around 21,700 lb. may be carried over 2800 n. mi. Provision for additional fuel in the center section may yet be made, extending the range even further.

Weight vs. Range

Two main cruise plans are shown in Figure 5: one for minimum block time (which, of course, gives the greater increase of lift-off weight with range) and one for minimum fuel (or long range). It is anticipated that the minimum block time plan will be used unless the payload is limited by the higher take-off gross weight, in which case the altitude and engine thrust will be adjusted to give better range. It should be noted that each of these cruise plans is based on a constant altitude cruise, commensurate with the present thinking on traffic control. The touchdown weight, of course, is independent of range until payload must be off-loaded.

Speed vs. Range

The variation of both angular cruise speed and block speed vs. range is shown in Figure 6. Again, the two cruise plans are shown, maximum block speed and maximum range. At the medium ranges (up to 1500 miles) an angular cruise speed of around 610 mph is available, while at the longer ranges it drops to 530 mph. Block speeds are accordingly spread, 550 to 460 mph.

Field Length vs. Range

Note that landing is critical at around 5800 ft. up to ranges of 1000 to 1700 n. mi. (Figure 7). Beyond, take-off distance prevails, going to a maximum of 7100 ft. at the maximum allowable gross weight. Airports are already built in this pattern—longer fields at larger centers from which longer flights prevail. These distances are based on a standard sea level field, and of course, temperature and altitude affect them. Take-off distances increase approximately 3/4 of 1% per 100 ft. of altitude and 1/3% per °F above standard. Landing increases about 1/6 of 1% per 100 ft. of altitude.

Operation of the 880 at the Terminal

Handling the 880 on the ground is essentially similar to handling other present-day large aircraft. The 880 is highly maneuverable and easy to handle, under its own power or under tow.

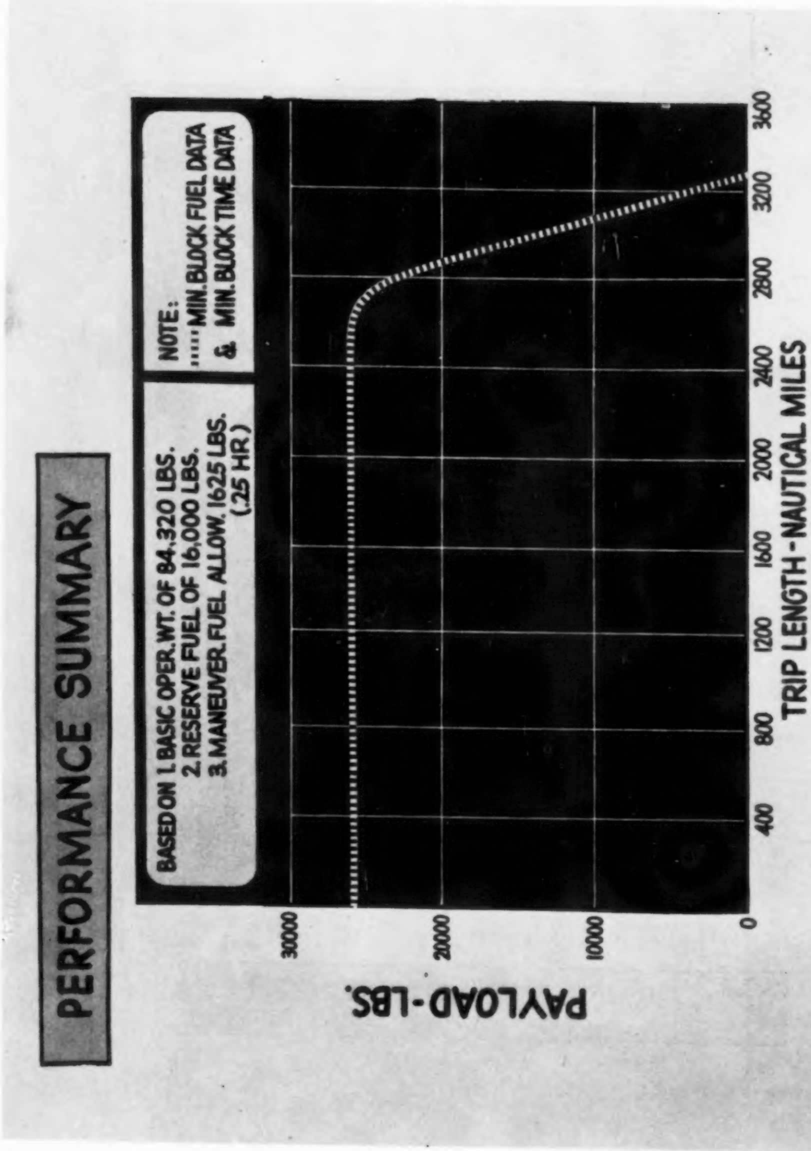

PERFORMANCE SUMMARY
BASED ON 1. BASIC OPER. WT. OF 84,320 LBS.
2. RESERVE FUEL OF 16,000 LBS.
3. MANEUVER. FUEL ALLOW. 1625 LBS. (.25 HR.)
NOTE:
..... MIN. BLOCK FUEL DATA
& MIN. BLOCK TIME DATA
PAYLOAD - LBS.
0
10000
20000
30000
400
800
1200
1600
2000
2400
2800
3200
3600
TRIP LENGTH - NAUTICAL MILES

Figure 4.

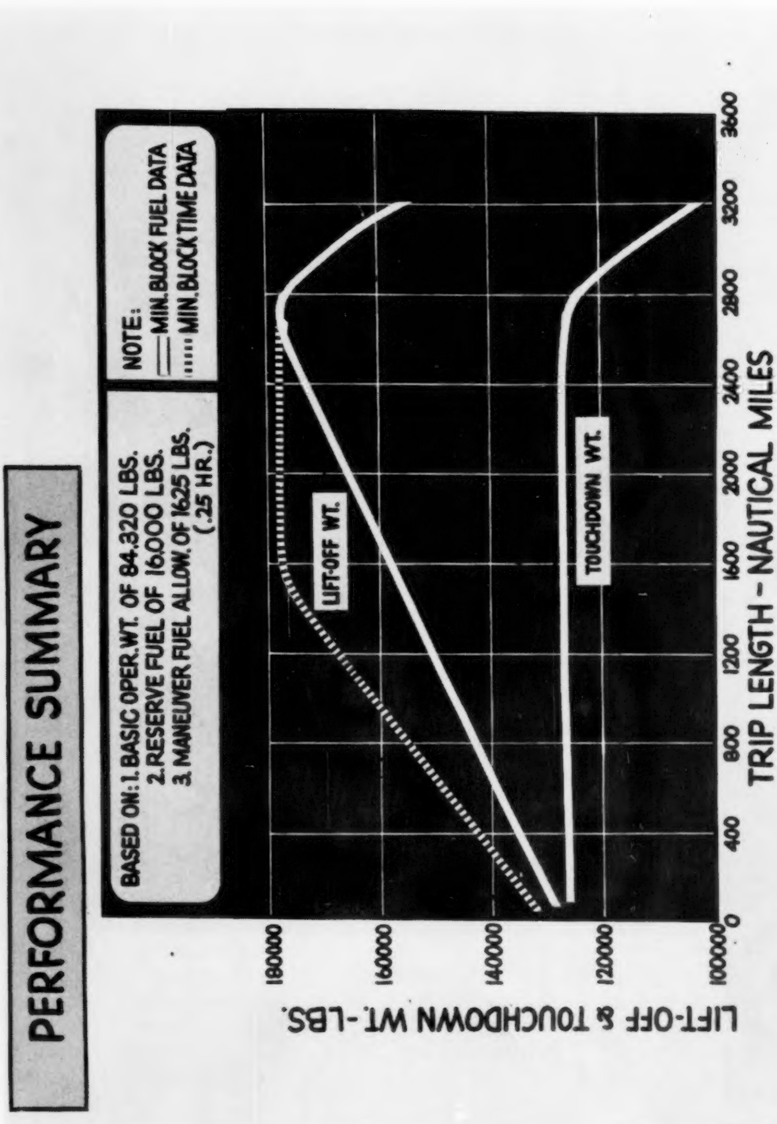

PERFORMANCE SUMMARY
BASED ON: 1. BASIC OPER. WT. OF 84,320 LBS.
2. RESERVE FUEL OF 16,000 LBS.
3. MANEUVER FUEL ALLOW. OF 1625 LBS. (.25 HR.)
NOTE:
MIN. BLOCK FUEL DATA
MIN. BLOCK TIME DATA
LIFT-OFF WT.
TOUCHDOWN WT.
LIFT-OFF & TOUCHDOWN WT. - LBS.
100000
120000
140000
160000
180000
0
400
800
1200
1600
2000
2400
2800
3200
3600
TRIP LENGTH - NAUTICAL MILES

Figure 5.

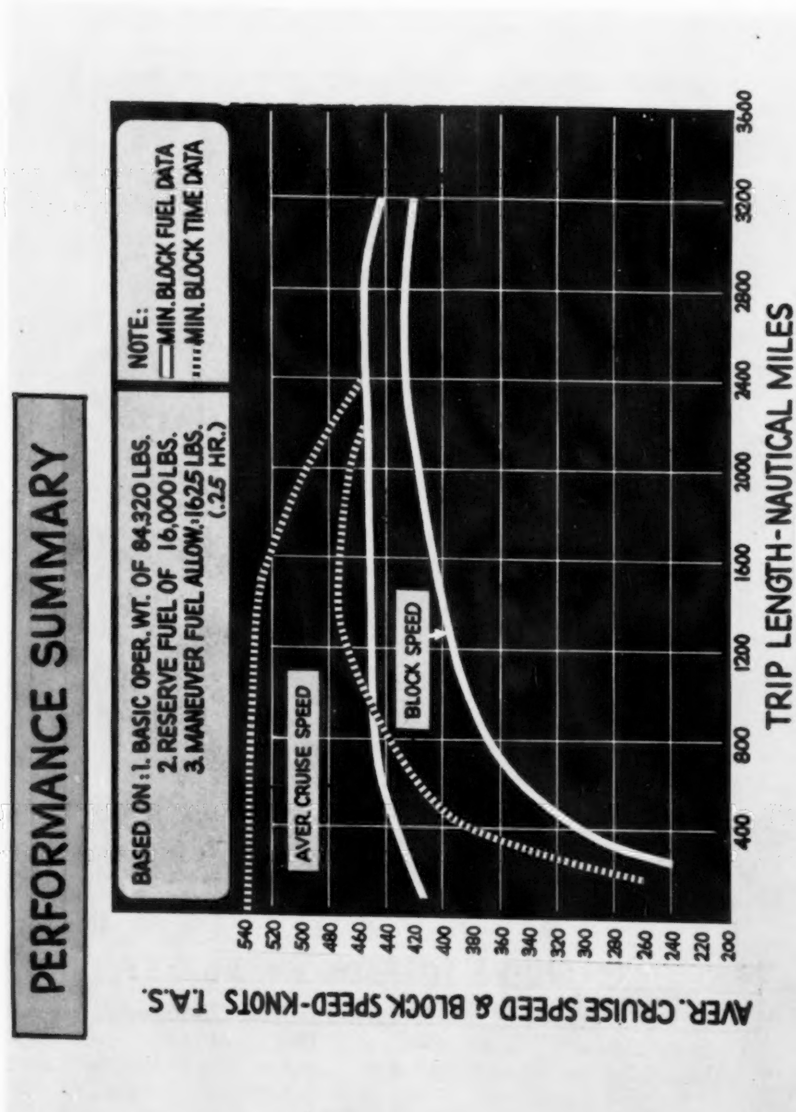

PERFORMANCE SUMMARY
BASED ON: 1. BASIC OPER. WT. OF 84,320 LBS.
2. RESERVE FUEL OF 16,000 LBS.
3. MANEUVER FUEL ALLOW.: 1625 LBS. (.25 HR.)
NOTE:
MIN. BLOCK FUEL DATA
MIN. BLOCK TIME DATA
AVER. CRUISE SPEED
BLOCK SPEED
AVER. CRUISE SPEED & BLOCK SPEED-KNOTS T.A.S.
540 520 500 480 460 440 420 400 380 360 340 320 300 280 260 240 220 200
TRIP LENGTH-NAUTICAL MILES
400 800 1200 1600 2000 2400 2800 3200 3600

Figure 6.

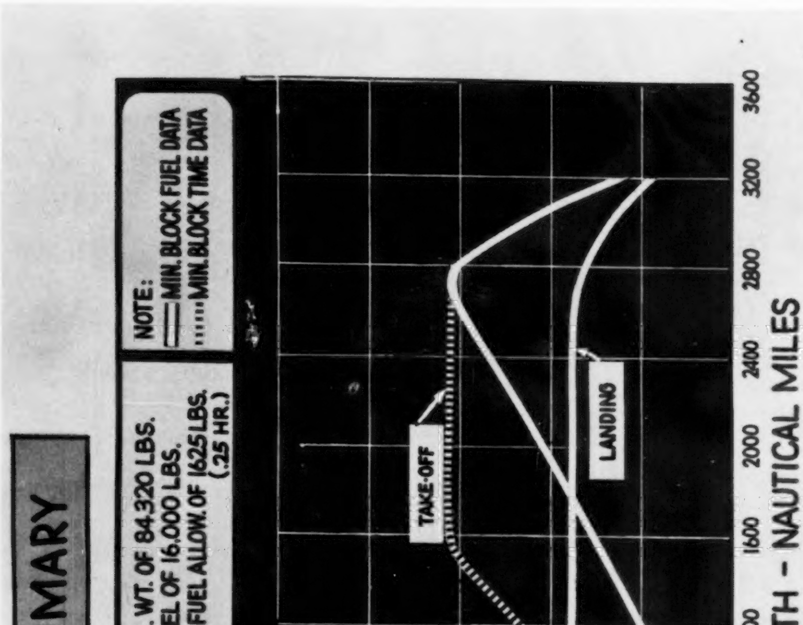

PERFORMANCE SUMMARY
BASED ON: 1. BASIC OPER. WT. OF 84,320 LBS.
2. RESERVE FUEL OF 16,000 LBS.
3. MANEUVER FUEL ALLOW. OF 1625 LBS. (.25 HR.)
NOTE:
MIN. BLOCK FUEL DATA
MIN. BLOCK TIME DATA
TAKE-OFF
LANDING
STANDARD DAY, SEA LEVEL - C.A.R. REQ.
TAKE-OFF & LANDING FIELD LENGTHS - FT.
9000
8000
7000
6000
5000
4000
0
400
800
1200
1600
2000
2400
2800
3200
3600
TRIP LENGTH - NAUTICAL MILES

Figure 7.

Take-off delays should be absorbed at the loading ramp before starting the engines to prevent unnecessary interference with other aircraft, minimize noise, and conserve fuel. This is possible because of easy starting and no warmup of jet engines.

The 880 will be taxied only on outboard engine to give better directional control and minimize the possibility of ingestion of foreign particles.

The 880 will taxi to the take-off area, start all engines and proceed to take off. Since the airplane will normally operate at shorter ranges, the take-off distance will usually be quite short. Similarly, since the gross weights will normally be medium and because of the high take-off gradient associated with this airplane, it will clear the take-off area quickly. The CJ-805 engine employs neither after-burning nor water injector, holding noise to a minimum. G. E. developed sound suppressors will aid noise reduction. Because the take-off is not augmented, the normal climb thrust is high, providing a rapid climb to altitude. Rate of climb at sea level will normally be around 4500 fpm.

During the descent of the 880 the 8.2 psi cabin pressure differential plays an important part. This cabin pressurization provides a sea level cabin at an airplane altitude of over 20,000 ft. Consequently, very rapid descents are possible from a holding altitude. The spoiler-speed brakes are also useful at the lower altitudes to provide rapid descent at low speeds. Holding on this airplane, as on all jet airplanes, is best accomplished at high altitude.

In Figure 8 the effect of both speed and altitude on holding fuel flow is shown. It is obvious that the holding will best be accomplished at altitudes around 20,000 ft. and with NO flaps.

Landing of the 880 will be accomplished in a quite normal manner. Pattern speeds will be around 160 knots, touchdown speeds around 125 knots. Speed brakes will be extended during the ground roll to provide maximum airplane weight on the wheels. Nose wheel brakes and anti-skid devices are also utilized to shorten the distance. After entering the terminal area the 880 will be handled in a conventional manner.

Turning Radius

The nose wheel may be rotated 70° providing a maximum tip radius of slightly over $83^{\underline{o}}$. The nose wheel itself will describe a circle with radius less than $57^{\underline{o}}$. Center of the turn will be outboard of the main gear to minimize scuffing of the tires. During towing the nose wheel steering may be disconnected permitting a 360° swivel. However, excessive angles will cause excessive scuffing. (Figure 9.)

Doors

In the terminal area the normal servicing will be necessary. Passengers use one of the two 30 x 74 inch doors, one forward and one aft. Opposite the main entry doors are 24 x 48 inch service doors. The cargo is located below floor level and is distributed in two compartments, one aft and one forward. 30 x 34 inch doors provide access. See Figure 10.

Unoccupied Areas

The unoccupied areas are located as shown in Figure 11. Electrical and electronic areas are just aft of the nose wheel compartment. Just aft of the

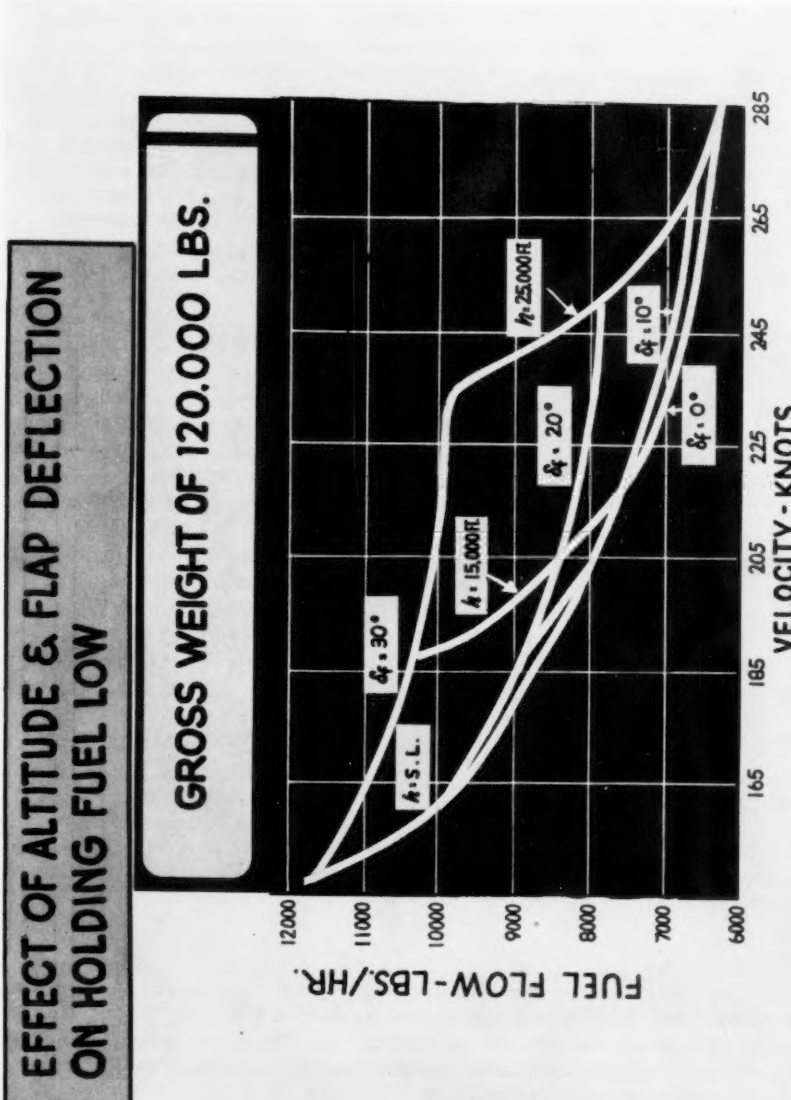

EFFECT OF ALTITUDE & FLAP DEFLECTION
ON HOLDING FUEL LOW
GROSS WEIGHT OF 120.000 LBS.
h = 25,000 ft.
h = 15,000 ft.
h = S.L.
δf = 30°
δf = 20°
δf = 10°
δf = 0°
FUEL FLOW-LBS./HR.
12000
11000
10000
9000
8000
7000
6000
VELOCITY - KNOTS
165
185
205
225
245
265
285

Figure 8.

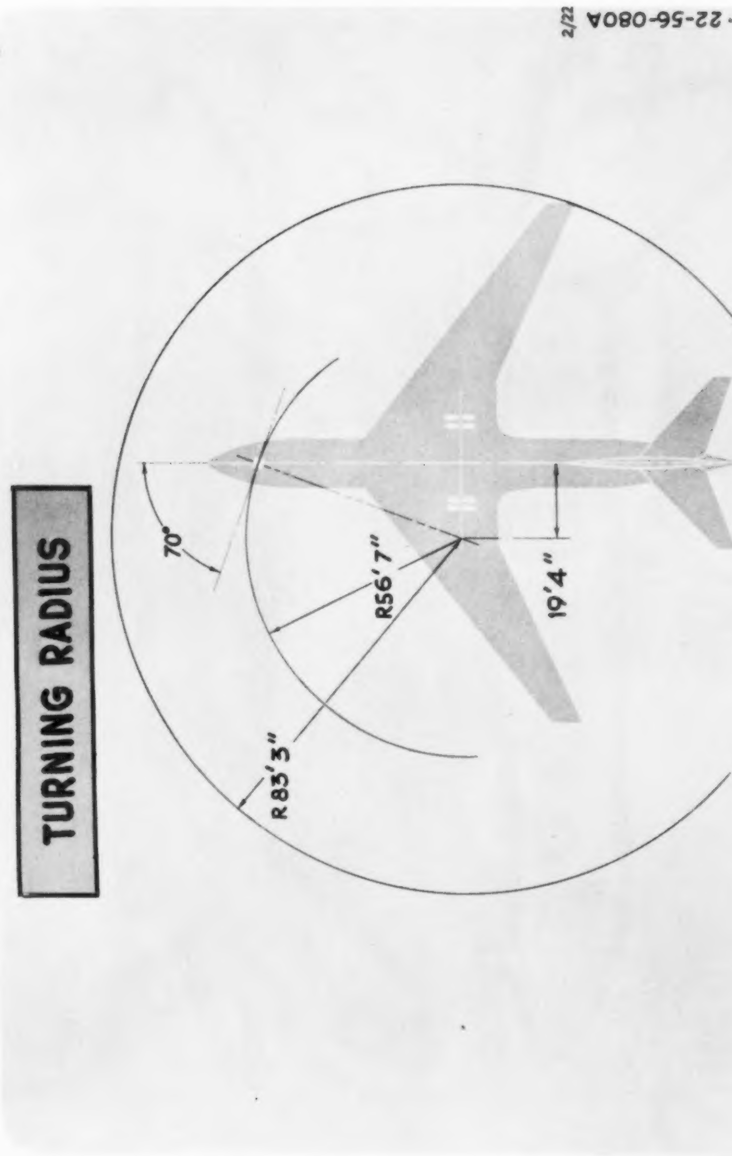


Figure 9.

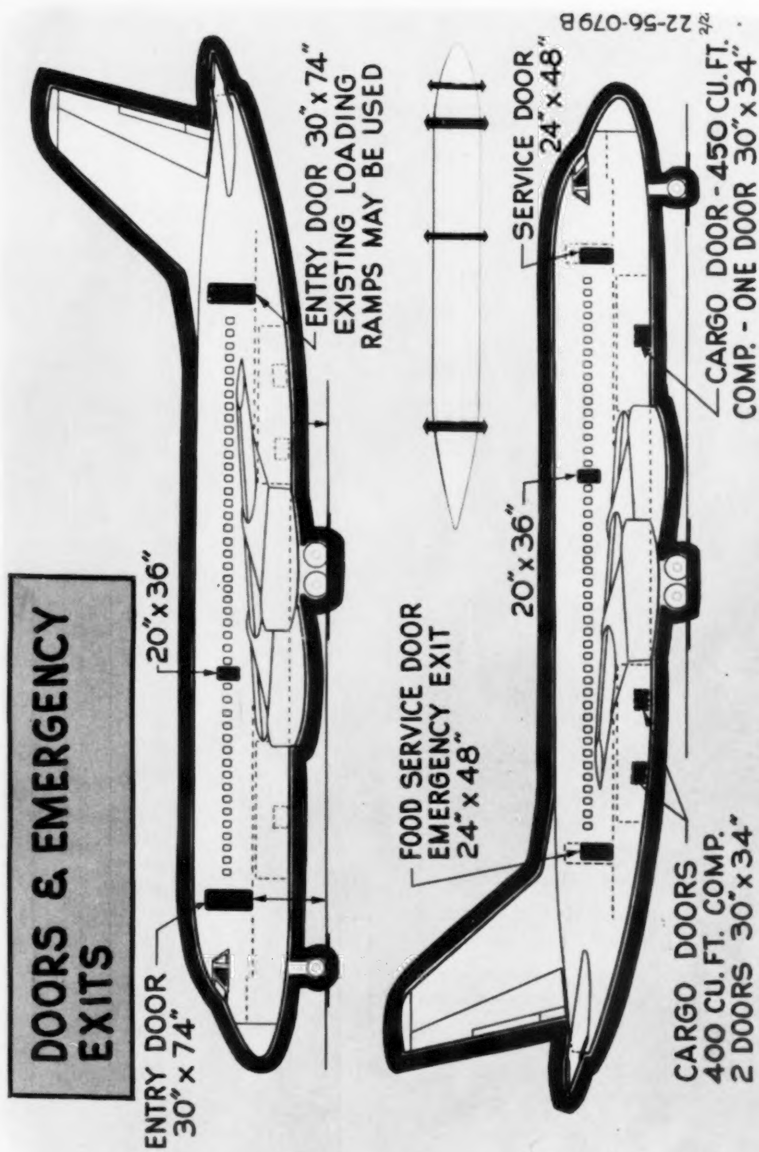

DOORS & EMERGENCY EXITS
ENTRY DOOR 30" x 74"
20" x 36"
ENTRY DOOR 30" x 74" EXISTING LOADING RAMPS MAY BE USED
FOOD SERVICE DOOR EMERGENCY EXIT 24" x 48"
20" x 36"
SERVICE DOOR 24" x 48"
CARGO DOORS 400 CU. FT. COMP. 2 DOORS 30" x 34"
CARGO DOOR - 450 CU. FT. COMP. - ONE DOOR 30" x 34"
22-56-079B

Figure 10.

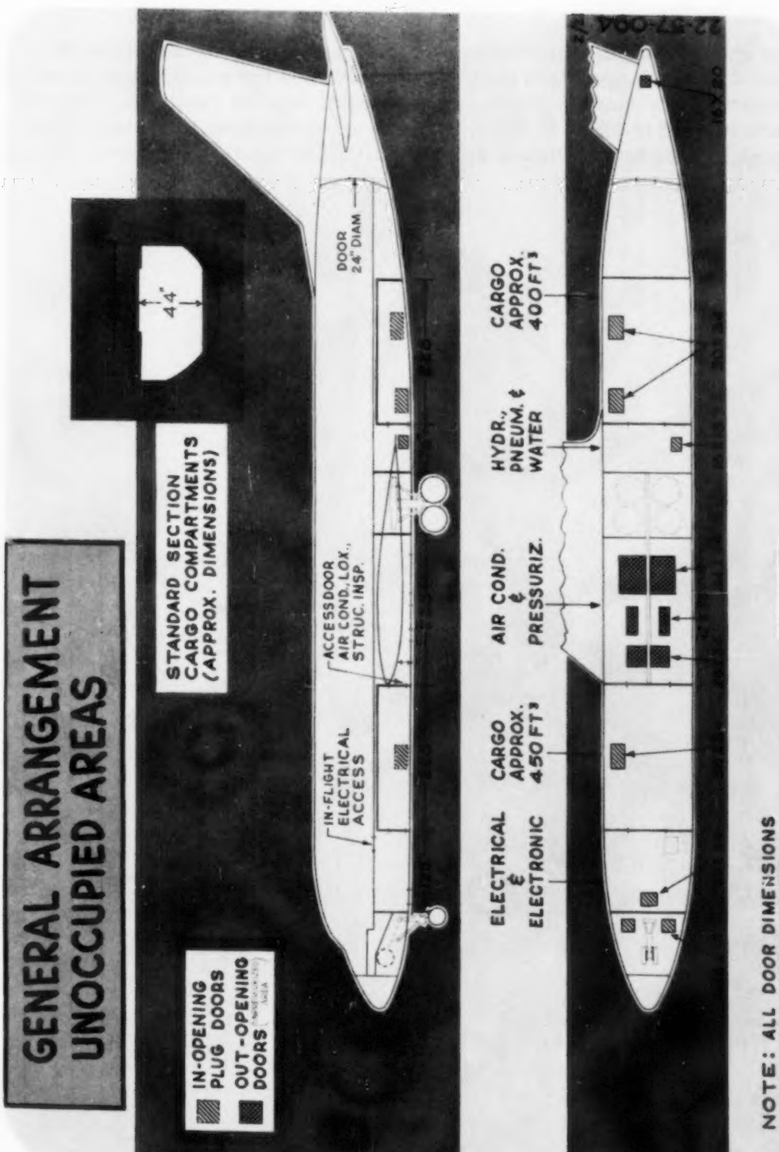

GENERAL ARRANGEMENT
UNOCCUPIED AREAS
IN-OPENING PLUG DOORS
OUT-OPENING DOORS
STANDARD SECTION
CARGO COMPARTMENTS
(APPROX. DIMENSIONS)
44"
DOOR 24" DIAM
ACCESS DOOR AIR COND., LOX., STRUC. INSP.
IN-FLIGHT ELECTRICAL ACCESS
ELECTRICAL & ELECTRONIC
CARGO APPROX. 450 FT³
AIR COND. & PRESSURIZ.
HYDR., PNEUM. & WATER
CARGO APPROX. 400 FT³
NOTE: ALL DOOR DIMENSIONS ARE APPROXIMATE.

Figure 11.

forward cargo compartment the air conditioning and pressurization equipment is located.

Ground Servicing

The ground servicing methods of the 880 are a direct development of practices to which operators have been accustomed for years. Nothing extraordinary in the way of equipment, manpower, or time is required. The 880 will be serviced in about 25 minutes from engine shutdown to restart. Most functions may be accomplished with adaptations of existing equipment. (Figure 12.)

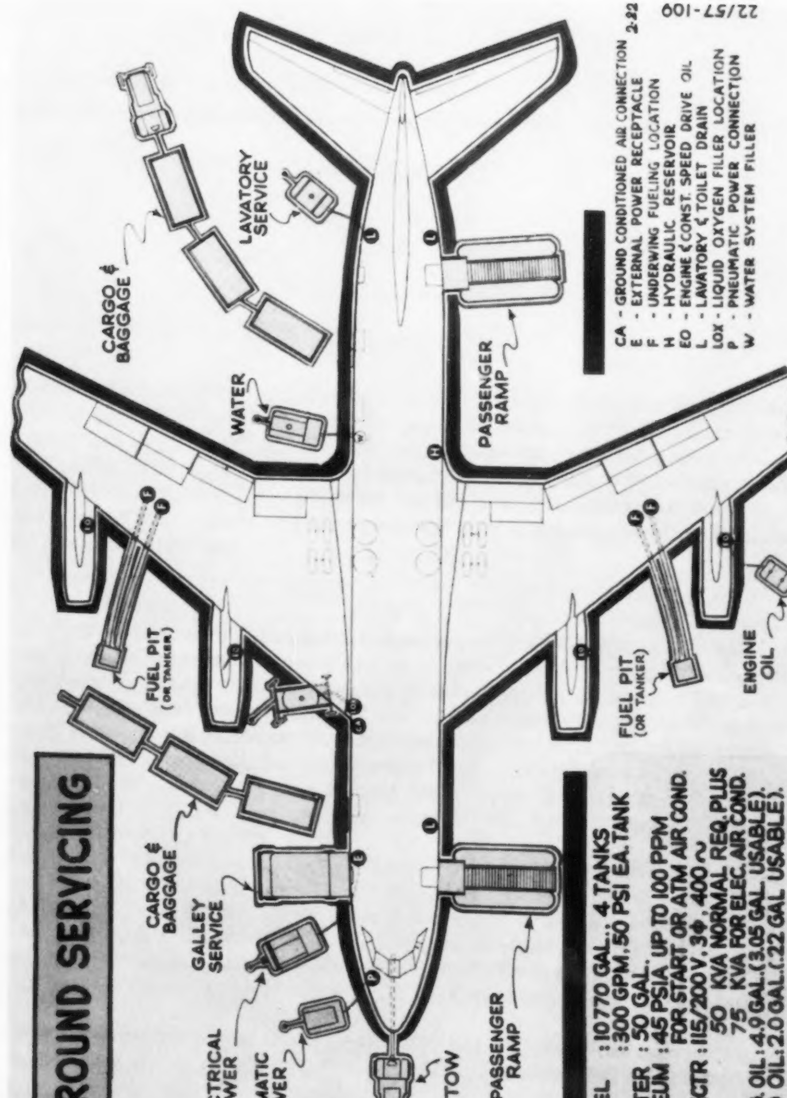

GROUND SERVICING
ELECTRICAL POWER
PNEUMATIC POWER
TOW
GALLEY SERVICE
CARGO & BAGGAGE
PASSENGER RAMP
FUEL PIT (OR TANKER)
WATER
CARGO & BAGGAGE
LAVATORY SERVICE
PASSENGER RAMP
FUEL PIT (OR TANKER)
ENGINE OIL
FUEL : 10770 GAL., 4 TANKS
: 300 GPM, 50 PSI EA. TANK
WATER : 50 GAL.
PNEUM : 45 PSIA UP TO 100 PPM
FOR START OR ATM AIR COND.
ELECTR : 115/200V, 3φ, 400~
50 KVA NORMAL REQ. PLUS
75 KVA FOR ELEC. AIR COND.
ENG. OIL: 4.9 GAL. (3.05 GAL. USABLE).
CSD OIL: 2.0 GAL. (.22 GAL. USABLE).
CA - GROUND CONDITIONED AIR CONNECTION
E - EXTERNAL POWER RECEPTACLE
F - UNDERWING FUELING LOCATION
H - HYDRAULIC RESERVOIR
EO - ENGINE & CONST. SPEED DRIVE OIL
L - LAVATORY & TOILET DRAIN
LOX - LIQUID OXYGEN FILLER LOCATION
P - PNEUMATIC POWER CONNECTION
W - WATER SYSTEM FILLER
2-22
22/57-100

Figure 12.

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

JET AGE PLANNING[a]

James T. Pyle[1]
(Proc. Paper 1472)

SYNOPSIS

Jet transports are not going to obsolete all our airports in a single day as some early jet hysteria threatened. Terminal buildings, surface traffic control, ramp fuelling and servicing facilities are due for revision and improvement. Traffic control of this new and faster family of planes is our greatest problem, but our $810 million program for the next five years will solve it. Certification of U.S.—made and foreign-made jets is another big CAA job and we are also on top of that.

The Civil Aeronautics Administration conquered quite a jet age problem when the new jet transports were first announced. Public imagination caught fire: Here were planes that would carry people faster than sound. Writers took off on air-cooled typewriters and shrank the world to a nubbin. They stretched runways out of shape, wrecked municipal budgets galore, and had engineers and the CAA hanging on the ropes trying to explain that all this wasn't necessarily so. It was the typical hysteria of the American with anything new in his hand. It gave everyone quite a ride, but it is now pretty much under control.

At last people know that no great armada of jet transports is going to descend upon their airports at half past two next month. However, they are going to swarm, eventually. While they will be appearing by ones and twos at first, figures now show that by July 1, 1961, there will be a total of 466 of the largest of the new jets, the 707, the DC-8, and the Convair 880. That is a large proportion of large planes in an airline fleet which today totals about 1,800.

Now it is understood that the airports of today generally have runways long enough and paving strong enough to take care of expected jet transport

Note: Discussion open until May 1, 1958. Paper 1472 is part of the copyrighted Journal of the Air Transport Division of the American Society of Civil Engineers, Vol. 83, No. AT 2, December, 1957.

a. Presented at The Jet Age Airport Conference, May 15-17, 1957.

1. Administrator of Civil Aeronautics, U.S. Dept. of Commerce, Washington, D.C.

planes on the air routes which they will serve. Now it is known that the heavier planes are not going to sink through their concrete runways.

All this shows progress. At last problems are in proper perspective and are being worked, and public hysteria has changed to intelligent, watchful interest.

The problems, in the order of their importance, are as follows: First, the existing needs of air traffic control must be met. Second, because there is some time to plan and prepare, the long-range needs of air traffic control must be met. Thereby, of course, hangs a tremendous tale—one to be written over the next many years. Third, new aircraft, especially jet-powered aircraft must be certified; and fourth, these aircraft must be supervised for safety.

Because it is felt that there is a reasonable good national system of airports and because the benefits of a program of federal aid have been enjoyed for many years, the writer would place airports as the final problem of the jet age.

Jet transports are not going to make obsolete all the airports in a single day, as some of the hysteria threatened, but they are going to require serious planning and some changes at many airports. The principal areas of the change will be in the size and design of terminal buildings, the runway and taxiway layout, ramp facilities and ramp management, and airport surface detection radar, in addition to the relatively few runway extensions and paving changes which may be required when more is known about how airlines will use their jets.

Over a period of years, many airports must enlarge their terminal buildings. There will soon be planes in service which will carry from 100 to 150 passengers. When frequent schedules unload and load passengers in this volume, a different size of terminal will be needed and one that is better designed for the efficient flow of so many passengers to and from the airplanes. Here is work and opportunity for ingenious architects.

On the ramp the jet brings new problems, a chief one being fuelling equipment and methods. A jet can demand 20,000 gallons of fuel at a major terminal of one of its long-range flights. The jet exhaust and the jet intake present new safety problems for airport personnel, for whom the CAA feels the same concern as for passengers in flight.

Airport surface movements must be speeded up. This is one way of increasing the capacity of an airport. It is done by making it possible for the big, new planes to make turns off the runway at 60 or 70 miles an hour instead of slowing down to 10 or 20 miles an hour. This clears the runway, and the traffic controller can bring in the next plane faster. CAA standards will soon be set for these rapid turnoffs, and work is being done on the troublesome problem of lighting these turnoffs for quick identification by the pilot at night.

Traffic on an airport surface can become badly snarled when the controller cannot see the limits of the airport and when the pilot himself can get lost in darkness or thick weather. In fact, an airport can be closed to all traffic if a single plane is moving about over its surface and the controller and pilot do not know where it is. The answer is Airport Surface Detection Equipment, 74 sets of which it is hoped will be ordered for major terminals. This equipment is a short-range radar by which the controller can move planes about on the field by "seeing" them on his radar.

As part of this jet-age planning, the CAA has been reorganized along lines that the writer feels are more realistic in view of the problems presented by the jet age. Airways aids and air traffic control naturally get some top billing in this reorganization. Airways efforts have been divided into two offices one to specialize in the design, installation, and operation of airways facilities, and the other to specialize in air traffic control. With the new aids planned, for which the money is now available, the airways can be brought up to date, overcoming shortcomings that have existed for many years.

The five-year, $810,000,000 program will enable this to be done, but the writer does not feel that this will be enough. When the complete report and recommendations of the President's Aviation Planning Committee, headed by General Edward P. Curtis, are published, there will be vista ahead full of other problems. The CAA can handle these problems because this agency is staffed by dedicated and competent personnel, and the writer has the greatest confidence that it can handle its part in the expanding aviation picture.

Incidentally, this huge program does not anticipate or conflict with any recommendations of the Curtis Committee. We have been working hand in glove with the experts on that committee, and the Federal Airway Plan has the endorsement of General Curtis. The CAA regards this program as a necessary, immediate measure to bring the outgrown airways system up to date; the Curtis Committee, which declares our program is in line with the long range objectives, is in full agreement.

This tremendous program is far too complicated to describe briefly. Actually, the CAA is buying the biggest pair of binoculars ever conceived, so that all the traffic can be "seen" on the 90,000 miles of federal airways. This means radar, of course, and eventually, through its use, airlines will be completely equipped to control traffic safely in even more crowded skies.

Beyond this, the speed and number of new planes and the demands they make upon the supply of air space, which is definitely limited, force the abandonment of the present method of conversation between pilot and controller. Decisions must be instantaneous. Instructions must be brief (coded preferably) because conversation is too time-consuming. In fact, traffic must be controlled as fast and as accurately as are the lights at a street corner, or as by a policeman who merely nods his clearances to drivers. This will take some doing, as can be readily imagined, but in view of twenty years of air traffic control experience and with the concentrated research and development program proposed by Mr. Curtis, it should be possible to work out advances that will keep the system currently safe and efficient.

The CAA is facing probably the heaviest workload in the certification of new planes that it has ever faced. A CAA team of engineers recently completed a survey of foreign-made jet transports and other planes which have been offered for certification between now and 1960.

A status report on the new planes might be of interest, as well as the probable timetable of their appearances on the air routes. Recently, another jet team of engineers was sent to Europe to investigate factories where planes are being prepared for United States purchase. These engineers reported a fairly staggering total of such planes, staggering at least to the CAA which must certify them for safety according to U.S. standards. They also have much better statistics than ever before on when these planes will be ready for certification and delivery to American purchasers.

There are eleven turbine-powered transports, each presenting its special problems. The United States has "executive agreements" with several

European countries through which their statements are accepted that their planes meet U.S. safety requirements for certification. In turn, statements that U.S. planes meet their requirements are accepted by them.

This is never as simple as it sounds. In every case there are special requirements which the United States feels impelled to make, some of them major requirements but most of them minor. Both parties to the agreements can impose these special requirements, which results in many engineering conferences and visits back and forth across the Atlantic. (It is interesting to know that there have been American engineers in the factories of every foreign plane proposed for sale in this country.)

These eleven foreign-made turbine-powered transport planes are due on the U.S. market between now and 1960. Twelve pure jets and one turboprop plane are due during the same time from U.S. factories; these are transport planes only. In addition, nine new helicopters and sixteen new, smaller planes are coming along as our routine certification work.

A few immediate problems in certifying these new transport planes are:

1. The planes will fly at higher altitudes, thus intensifying the problems of cabin pressurization.

2. They have swept wings, which present problems in control and cross-wind landings, and a myriad items of engineering to check in carrying the bending loads around a corner and through the fuselage structure.

3. Aerodynamically, they are very clean airplanes. How can they be slowed down in flight? How can the problems of braking or reverse thrust in cutting down the landing roll be handled?

4. Electrical systems are different, more powerful, and more complicated; 40 KVA alternators on each engine are included.

5. "Pure" jet engines gulp fuel at a tremendous rate, and fuelling equipment and methods must be safe.

6. These planes fly faster. The windshields must be strong enough to resist impact with a four-pound bird at cruising speeds.

As to when these planes are to appear, it is not possible to guarantee the dates, but they will be approximately as follows:

A stretched version of the English Vickers Viscount used by Capital, the Model 800 with slightly higher weight and power, is due to go into operation with Continental about a year from now.

Another British transport, the Bristol Britannia, Model 300, is expected to go into service on Northeast Airlines routes late this Fall. The takeoff weight, 170,000 lbs., is somewhat greater than the latest U.S. transports, but the runway loading problem should be easier than with present large transports, because it employs a four-wheel, dual-tandem main gear.

The Dutch Fokker F-27 is a high-wing, local-service transport using two Rolls-Royce Darts similar to those in the Viscount. Fairchild is tooling to build it in the U.S., and should go into operation with Piedmont and others late this year or early next year.

The only U.S. transport in the turboprop class is the Lockheed Electra, powered with four Allison engines. The Electra has been ordered by American, Eastern, and other airlines and is scheduled to go into operation late in 1958. Here again, a modest takeoff weight, 113,000 lbs. and a 5,000-to-6,000-ft. runway requirement should present no new basic problems.

However, the straight jet transports, which will bring very substantial advances in speed and in load-carrying capacity, will provide new airport and

terminal problems. The first of these transports is the Boeing 707, the prototype of which has been flying for several years, powered with the Pratt & Whitney, J57-type engine. It is scheduled by the manufacturer to complete its CAA certification tests by the summer of 1958. The first planes of this type will go to Pan American and American. The takeoff weight at the Boeing 707 should be a little over 240,000 lbs.; other versions of this basic design, using higher powered engines and with a slightly larger airframe, are scheduled to be approved within the following year.

The next plane in U.S. operation should be the de Havilland Comet ordered by Capital for delivery late in 1958. This airplane, grossing just over 150,000 lbs. and powered with the Rolls-Royce Avon, is an intensively developed and modified version of the Comet which pioneered jet operations for BOAC. The hard lessons learned in that operation have been completely applied.

Next in the big-jet field should be the Douglas DC-8, powered with the J57, which is scheduled for certification in September, 1959. Other versions, with J75 and Conway power plants, should be certified within a few months thereafter.

The final entry will be the Convair Model 880, powered with the GE J-905. This transport, with a takeoff weight of about 180,000 lbs., is intended for use primarily on routes shorter than the U.S. transcontinental, nonstop service.

Certification of these planes is not the last word; their operation will present other new problems. Fortunately, there is time to prepare, but no time to spare in getting ready for them. Air-carrier inspectors are going through jet refresher courses at the training center at Oklahoma City. Jet trainers have been borrowed from the Air Force for this purpose. A simulator of a jet transport is being acquired, by which money can be saved on familiarization training. The CAA has a respectable number of men who have had recent military aviation experience, and pilots who have jet time are currently in good supply. The main objective is to have them ready for their duties when the first jet transports appear.

Only those problems the jets will bring to the airports have been touched upon, but these are uppermost on the programs of the airport managers in their two big national associations. City authorities have their problems in the never-ending growth of air commerce and the demands it makes on air terminals. Because there are going to be jet-powered planes for use on feeder lines, these problems are not confined to the big city terminals.

One can no longer say the "forthcoming" jet age. Everyone is in the middle of setting the house in order for the visit of what has been described as "a whole new family of airplanes." It is believed that jet transports will bring about one of the most significant advances ever made in air transportation.

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

TRAFFIC ESTIMATES AND AIRPORT ECONOMICS[a]

Kenneth A. Osterberg[1]
(Proc. Paper 1473)

Designers who will be working on airport projects have an important part to serve in the future of air travel. They will be involved with this industry at the critical point where a municipality is going to spend a great deal of money for airport facilities. If they do their job well and influence their municipal clients to be thoughtful and frugal in the building of these airport properties, they will affect the prosperity of many people. Their work may make the difference as to whether this industry can expand to meet the public needs or will be cut short by excessive costs.

The transportation of goods and people has been a basic requirement for the growth and maturity of most civilizations or countries. A higher standard of living for all of the people has followed better transportation. More rapid distribution of goods and services has made more products available to more people at lower cost. Increased commerce has produced more jobs at higher pay. The opportunity for people to travel has added to their knowledge and has diminished their provincialism and intolerance.

The airplane is the break-through into a new medium for the movement of goods and people; it has limitless potentials for the public good. But it won't grow to its optimum size if inadequate planning makes it cost too much. Governments and private industry are both subject to the same economic law; the cost effect of any service will determine the spread of its use.

For this reason the American public has a direct interest in air-transportation economics. The people have much to gain by helping to create a successful aviation industry whose impact on commerce in general will increase this country's wealth. Air transportation can become a national resource as important as oil or iron. World social changes of great consequence will be directly influenced by the airplane as a commercial vehicle.

In this country the airplanes engaged in commerce are owned and operated by private industry. This private industry, however, does not own or control the airports which are indispensible to airplane use. The airports

Note: Discussion open until May 1, 1958. Paper 1473 is part of the copyrighted Journal of the Air Transport Division of the American Society of Civil Engineers, Vol. 83, No. AT 2, December, 1957.

a Paper prepared for presentation at Jet Age Airport Conference, New York, N.Y., May, 1957.

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are built and owned by government, mostly municipalities. Thus the private industry air-carriers must use the government owned airports or no air transportation will occur.

Airport use-fees are paid by the air-carriers to compensate municipalities for use of airport field and runway facilities, and rentals are paid for occupancy of airport terminal buildings.

Private industry in this country, and air transportation is no exception, is regulated by the force of economic feasibility. Projects that make money succeed and go forward, those that lose money fail and disappear. Just as fundamental is that the selling price of a service will determine whether it will have wide-spread general use or whether it will be small, specialized and limited. At a given airline ticket price a certain number of persons will ride, at a lower price more will ride, at a higher price fewer. At some high price no one will ride. If a large proportion of the American people are to have the individual and national benefit of air transportation, tickets must be inexpensive.

If there is going to be air transportation for the many, it must be learned from the past that some of the things which have been done to most of the other common-carriers cannot be done to air transportation. By political opportunism, by thoughtless tax devices, by government-imposed unnecessary cost burdens, one by one the economic feasibility of all of the common-carriers of people have been destroyed. The railroads can't carry passengers at a profit; the inter-city motor-coach lines are almost failing; the city transit lines have been reduced to where they need a complete financial rebuilding which will recognize that an urban area must have low cost public transport to survive.

The people of this country have to assume that the private industry air-carrier companies, dealing with their own money, will on the average make fairly good decisions about their own economic welfare. The airlines will probably average-out buying the right amount and kind of airplanes, and will manage their businesses acceptably, because their capital and profits are immediately affected by those decisions. They will make many mistakes, but because most of their capital is committed to current operation, or to equipment which soon wears out and shortly allows a new decision, they will have repeated opportunities to recover from their errors.

It appears that one of the major contributors to rising air-transportation expense may be the airport-planning decisions which are the responsibility of the municipalities. Cities won't make bad decisions knowingly, but even though costly airport mistakes are the result of lack of knowledge, the expense effects of those mistakes are almost as bad.

There will be fewer mistakes if plans for design and construction are based on a thoughtful evaluation of what is known and can be anticipated about the aviation industry. It is the job of the designer to develop as much knowledge as is possible so that economic guide lines are available.

The burden of airport costs eventually fall on the public one way or another. That portion of a city's airport expense which is transferred to the airlines through use-fees or rents is inevitably reflected in the passenger ticket price. The portion of airport expense covered by concession revenues is public expense paid by the public's patronage of the concessions. Tax support is direct public participation. None of this is wrong, it is stated only to be a reminder that costs don't disappear. The shifting around of the payment burden doesn't change the fact that as an end result the user of the air-carrier

service, or the public, finally pays all airport expenses; the airline stockholder doesn't, the concessionaire doesn't.

Allow the airport costs to go unnecessarily high because of poor planning or mediocre airport management and it may be found that air transportation will cost more than most of the public can afford.

It is generally accepted as true that people ride any common-carrier only because it serves their travel needs at a cost commensurate with the travel service rendered. They do not use a medium of travel because of luxurious terminals; all of their requirements are met if the terminals are clean, orderly and convenient. Airport terminal construction beyond meeting traveler's needs will raise airport operating costs, and increased costs will inevitably be paid by airplane passengers or the public in one way or another.

It seems reasonable to suggest that an airport terminal lobby should be built the size and shape the passengers need instead of some other way. If over-design unnecessarily raises the cost of an airline ticket so that some people can't afford to ride, the design has failed.

Airport runway, taxiway and field facilities construction isn't subject to the same design excesses as terminal buildings. While requirements for runway lengths, strengths and wind coverage change as new aircraft are produced, this process is slow and is one of evolution. For this work, there are reliable design standards continually being formulated by technical experts.

Often not enough care is exercised to use airport land thoughtfully for its most important functional and economic purposes. Most metropolitan airports require more land than was anticipated in the past; acquisition of adjoining property in most cases can be done only at almost prohibitive expense. Location planning of airport installations which allow a choice should try to anticipate and forecast the increasing land-space demands which will accompany this changing and growing industry.

If cities are to avoid bad planning in order to eliminate excessive costs, what things must be forecast to make the plans better. What is it important to know about an airport before a plan is made and construction started.

Primarily it must be accepted that in an industry changing as rapidly as air transportation, the best forecasts will be imperfect. Wherever possible the designer must avoid creating airport facilities which cannot be expanded and modified without major loss when changing kinds of aircraft and increased quantities of people must be accommodated.

This general rule of being careful not to build one's self into a hole isn't enough, however, one still has to know how big to build it, how little is sufficient, how much is excessive.

Engineers normally work with the description of things in the finite terms of miles, feet and inches, square feet or cubic feet. To create the design-criteria for many of the airport facilities, it is important that he supplement this with forecasts based on the less tangible factors of population trends, spending habits of people, future travel preferences, mechanical improvements to aircraft, the future value of money, the future spendable income, and the price the public will have to pay for an airplane ticket, because all of these factors will influence how many passengers will ride on how many airplanes.

Basically the problem is to try to determine from such knowledge as is available how to avoid wasting capital by building unnecessarily-high-expense facilities; to calculate the capital investment that must be made for the things that are truly required and to identify and eliminate the things wanted but not

needed. This doesn't always win friends for the designer because municipalities and airport tenants often have objectives in conflict with economics.

All planning of airport terminals and of field and runway facilities must start with an estimate of the number of passengers that will be served. It is known how many passengers ride aircraft today, but how many will ride in 1960? In 1965? 1970? It would be difficult for a person to try to answer that question by applying it to himself individually. He doesn't know how many miles he will travel by air in each of those years, nor how many trips he will take. The forecaster doesn't know, but he can make an estimate of how many American people in the mass will be air passengers in each of those years. He does it empirically by determining what people did in the past and assuming that they will follow some kind of a pattern in the future. He knows that they won't do in the future exactly as they did in the past, but he will have good reasons for his variations.

Many agencies, companies and individuals are constantly developing estimates of the future quantity of airline passengers. All of their work is available in various reports and publications. While there are minor differences in the results of their work, and even though various forecasters base their opinions on different premises, they all end up with passenger-growth forecasts which can aid one. It is the qualified opinion of the writer that airline passengers in 1970, for instance, can exceed three times those of 1955.

Design planning must try to evaluate what airport accommodations these travelers will need; how many automobile parking spaces, how many square feet of lobby area, of restaurant and concession area, of airline operations space. How many airplane loading positions will be required.

To find answers to these questions, the airport designer must analyze what people do on airports today, what they need, how much they need. He can relate square feet required for the various airport functions to the number of people using them, and then recognizing that the travel habits of people change and that the airplane vehicle itself will be altered as time passes, he will make design decisions taking care to keep his design fluid so that the unknown can be accommodated.

It seems advisable that the designer should not try to build today what the aviation industry will need in 1975. He doesn't know what it will require then and no one else does. Cities should build now what is provably needed in the immediate future with expansion availability for adjustment to changing conditions.

Cities must conserve their money by building tight, by providing a high proportion of rentable to total area in terminal buildings, remembering that each square foot of public space in a terminal building will annually cost a city approximately \$4.00 to \$6.00. Extra unnecessary square feet cost the same as those that are required; good design can eliminate this waste.

One of the major advantages of air-travel is speed. The air-passenger desires to stay at an airport as short a time as possible. The airport is just a way station as far as he is concerned, a necessary part of traveling a long distance. As airline service improves because of more frequent departures and more precise scheduling, the present passenger-occupancy time at the terminals will diminish. If there is less time spent waiting, there will be less lobby space required per enplaned passenger. With less time spent at the airport terminal, the passenger will buy fewer things, so requirements for concession areas per enplaned passenger more than likely will diminish.

As air transportation in the public mind becomes more utilitarian, as it becomes a completely commonplace medium of travel, then the functional service it renders will be more important than the package it is wrapped in. Today's impressive airport-terminal package may be tomorrow's inconvenient and uneconomic reminder that people at a transportation terminal want to travel, not have a spacious shopping area in which to wait.

Experience has shown that an airport construction project based on good passenger forecasts, carefully planned to create the amount and kind of building space and other facilities actually required, can qualify for, deserves and will get public-financing support.

From reliable traffic forecasts statistics can be produced for any airport to estimate the future revenue per enplaned passenger to be derived from airport restaurants, auto-parking lots, ground transportation companies and various other concessions. Also to determine how many plane loading positions will be required, how many square feet of lobby, of concession area, of airline operations space. The annual operation and maintenance costs and annual interest and depreciation expense of airport facilities and buildings are normal mathematical computations. From the foregoing it is not difficult to determine if a proposed airport design plan is economically feasible. Over-design or poor design will be evident if it exists, and good design will be its own witness.

If the people, the public, are made aware that growing air transportation will have an important impact on their individual lives and fortunes, their interests will be identified with the airport project, and if they know that an airport plan is economically feasible because design has been closely guided by public needs, they will produce the capital funds required for construction.

It is appropriate to ask if there is any hope of designing an airport terminal right. Do the compromises which are necessary to resolve the different ideas of the air carriers, the concessionaires, the civic leaders and the cost accountant become so confining that the product of the design work is inevitably a monstrosity?

The answer is that it is possible, even in this limiting framework, to build properly if the designer is able to show by good forecasts why a right way should be followed. If he stays with provable function, supported with sound economics, no one can question the results of his work. The aviation industry and the public can afford the costs which will result from that kind of construction. As far as esthetics are concerned, there is great dignity and appeal to functional design; even municipalities are learning to be proud of usefulness.

Paper 1474 December, 1957 AT 2

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

PROTECTION OF AIRPORT APPROACHES[a]

Chester G. Bowers*
(Proc. Paper 1474)

SYNOPSIS

Studies regarding operating characteristics of turbo-prop and turbojet commercial aircraft show these aircraft do not create new problems regarding obstructions to air navigation. Consequently, no changes are contemplated by the Civil Aeronautics Administration in the criteria for determining obstructions to air navigation because of the use of jet aircraft in civil aviation.

Federal aviation agencies, including special study groups such as the Office of Aviation Facilities Planning, as well as the aviation industry have been busy forecasting the future development of civil aviation. The forecast emphasis is being put on long-range requirements for aviation facilities including airport facilities, as well as air navigation facilities. The report of Mr. Edward P. Curtis, Special Assistant to The President for Aviation Facilities Planning indicates that the six billion passenger miles flown by the scheduled airlines in 1946, which have increased to 22 billion in 1956, will be further increased to 60 billion in 1970. The forecasts of the Civil Aeronautics Administration indicate that this trebling of passenger miles will be accompanied by a trebling of air carrier passengers, along with a guadrupling of air cargo and a doubling of general aviation activity.

All of these forecasts point up the problem of more effective and efficient use of airports, as well as air space. The airport problem is not solely limited to providing adequate facilities to handle the airplanes and passengers on the ground. It goes further than providing sufficient landing and terminal facilities, including long enough runways and efficient taxiway systems with high speed turn-offs and warm-up areas. The problem of increasing airport

Note: Discussion open until May 1, 1958. Paper 1474 is part of the copyrighted Journal of the Air Transport Division of the American Society of Civil Engineers, Vol. 83, No. AT 2, December, 1957.

a. Presented at The Jet Age Airport Conference, May 15-17, 1957.

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capacity through stepping up the airport acceptance rate and the establishment of lowest possible minima, require consideration of other problems relating to getting the airplane into and out of the airport. Airport approach protection problems must, therefore, be given consideration along with other airport matters.

Airport approach protection, however, is not something to be thought of specifically in connection with the use of the airport by new and increased numbers of aircraft. The presently expanded air traffic and the increased spread of urbanization with its resulting encroachment on existing airports by residential, commercial and industrial development have highlighted the necessity of present and continuous consideration of airport approach protection problems.

Even at the present moment the economic or physical limitation on existing air commerce airports at Corpus Christi, Texas; Tallahassee, Florida; Muskegon, Michigan; Grand Rapids, Michigan; Rochester, Minnesota; Asheville, North Carolina; and Rocky Mount, North Carolina, is making it necessary to study the possibility and feasibility of undertaking construction of a replacement airport at these locations. Admittedly, approach protection problems are not the sole cause of the obsolescence of the existing airports, but in almost all of these instances are one of the factors contributing in a substantial degree to this obsolescence.

In this paper the problem of airport approach protection will be examined from the standpoint of the Federal interest in such matters, recognizing that it is the primary responsibility of the States and their political subdivisions to acquire such property interests and effect such control of the use of land in the vicinity of the airport as may be necessary to insure the continued availability of their airports to the public. The Federal interest stems from the mandate of the Civil Aeronautics Act of 1938 to encourage the development of civil aviation, and the objective of the Federal Airport Act of 1946 to establish a nationwide system of public airports adequate to meet the present and future needs of civil aviation. In carrying out these general responsibilities in specific connection with the protection of airport approaches, the Civil Aeronautics Administration undertakes to develop standards and criteria to determine and identify obstructions to air navigation, renders advisory service in the interpretation and application of the standards and criteria for individual airport owners and their consultants, and takes positive action through grants of funds and sponsorship requirements under the Federal Airport Act to eliminate and prevent obstructions to air navigation.

The criteria for determining obstructions to air navigation, as applied to U. S. civil airports, are set forth in the CAA Technical Standard Order—N18, dated April 26, 1950. TSO-N18 sets up a method of establishing certain imaginary surfaces in the air space surrounding the landing area of civil airports and provides that any objects, including such things as hills and trees as well as manmade structures, which project above the landing area or any of these imaginary surfaces shall be considered obstructions to air navigation.

It does not appear either necessary or appropriate to discuss here the details of the criteria established by TSO-N18. Suffice it to say, that the approach surfaces, the horizontal surfaces, the conical surfaces and the transition surfaces as established for the various categories of airports under TSO-N18, while somewhat complicated in their application to individual airports, are being satisfactorily used as a guide for determining obstructions to air navigation.

The criteria of TSO-N18 were developed by a study group of the Civil Aeronautics Administration in conjunction with the Federal Communications Commission, the Department of Defense and other appropriate branches of the aviation and broadcasting industries. In developing these criteria, that group made a painstaking analysis of all phases of problems on obstructions, paying particular attention to the characteristics of the aircraft of the future, those on the drawing board as well as those under development. The goal of that group was to develop standards which would be valid for a 20-year period. From all that can now be seen, the group was successful in this objective.

The studies of the Civil Aeronautics Administration heretofore made, and now being made, regarding the operating characteristics of turbo-prop and turboject commercial aircraft, show that these aircraft do not create new problems regarding obstructions to air navigation.

The salient points of this paper is to point out that, consequently, no changes are proposed or contemplated in the criteria of TSO-N18 because of the introduction and use of jet aircraft in civil aviation.

There is one noteworthy current development in connection with the specific problems of obstruction to air navigation caused by the increase in numbers and height of television and radio antennae. The radio/television industry must have tall antenna towers in order to provide the degree of public service contemplated by the Communications Act of 1934. However, these tall skeletal structures and their supporting guy wires are hazardous to aviation because they are hard to mark and hard for pilots to see.

A joint Industry-Government tall structures committee (JIGTSC) has been engaged for several years in developing standards to be used as a guide by both the radio/television and aviation interests in their consideration of mutual problems relating to the height and location of proposed new antenna structures and new airports.

The criteria being developed by this committee have the following objectives:

a) to provide protection for low altitude intercity air routes,
b) to provide increased protection for airways and much-used fly ways, and
c) to provide additional protection for areas in the vicinity of airports.

The final criteria as published will not be intended as a rigid standard to be arbitrarily applied by the Airspace Panel of the Air Coordinating Committee in approving applications for tower construction, and the criteria will not be applied to existing antenna structures.

While final decisions on all details of the new criteria have not yet been agreed to, it is proposed that the runway approach surfaces, as such are identified in TSO-N18, should begin at a point 2000 feet from the end of the runway rather than at 200 feet as is provided in N18. The horizontal and conical surfaces, as such are identified in TSO-N18, are being considered for extension. In the case of airports of maximum "Feeder" category and above, the conical surfaces may extend as much as 15 miles from the airport reference point. Final approval of these proposed criteria is expected momentarily. It should be particularly noted, however, that the criteria relating to tall structures, when finally announced, will not be applied to other than antenna towers.

Airport owners seek to protect the approaches to their airports by two general methods. The most effective and positive method of protection of airport approaches is the acquisition of interests in land, with such interest varying from a fee simple absolute to avigation or aerial easements. The second general method establishes a limitation on the height of structures which may be put upon land by legislation enacted under the police power. This method of approach protection, commonly referred to as airport zoning, is justified primarily as a regulation in the interest of public health and safety.

Airport zoning, or height limitation regulation, has several deficiencies as a sole effective measure for protection of airport approaches. Inasmuch as retroactive airport zoning is generally recognized as invalid, it may be noted first that such legislation is not effective as a means of eliminating existing obstructions.

A further deficiency is the inability of height limitation legislation to attach the problem of the celebrated Causby case (U. S. vs. Causby, 328 U. S. 256, 66 S. Ct. 1062). It will be recalled that this case involved low flights of aircraft in the landing and taking off from an airport in North Carolina, with resulting damage to a chicken farmer. In the Causby case and in other cases involving the same problem, the courts have held that a landowner was entitled to receive damages because of the flight of aircraft at such low altitudes and in such great numbers and frequency, that the beneficial use of the owner's property is destroyed. In other words, airport zoning does not carry with it, or create for the municipality or the public, a right of flight to the extent of granting immunity from suit by a damaged landowner.

Legislation enacted under the police power has a further inherent limitation when it attempts to restrict a landowner in the use of his land. The question here involves the extent to which a restriction may be placed upon the use of property without there being an unlawful taking of that property. If the zoning ordinance, or height limitation regulation, imposes such a restriction as would prevent the landowner from using his land for its normal or highest best use, or otherwise divests the property owner of a recognized property interest, there is a taking of property without compensation. This is contrary to the Constitution.

Instances have been noted wherein a municipality has passed an ordinance to zone to the ground, or at least place such a low height restriction as to prevent normal use of property. When the unreasonableness of the height limitation was called to the attention of local officials, sometimes the argument has been advanced that the zoning ordinance can be used as a big stick to discourage applications for building permits, and if the property owner threatens legal action, a variance will be granted. The right of private property is a cornerstone of our legal and business systems. It should not be capriciously invaded. No responsible public official should ever use an airport zoning ordinance as a bliff and force the property owner to accede to its restrictions or go to the expense of hiring experts and bringing legal action to protect his legitimate property rights. The adoption of an airport zoning ordinance should be based upon a careful balancing of the interests of the general public as against the rights of the landowner.

A municipality or other political subdivision has no inherent power to adopt an airport zoning ordinance. Since the right to exercise the police power rests with our States, unless and until there has been an appropriate delegation of such power to the political subdivisions to the State, their attempt to

exercise the power is open to attack. Accordingly, it is generally accepted that express legislative or charter authority to adopt airport zoning ordinances must be granted to local political subdivisions by the State as a basis for enactment of a local ordinance.

The rather negative approach to airport zoning taken here is not intended to indicate that airport zoning is an ineffective tool in affording airport approach protection in many instances. A negative approach was taken to emphasize that zoning cannot ordinarily do the entire job. It has been recognized by the Civil Aeronautics Administration for many years that airport zoning or height limitation legislation is particularly appropriate for consideration in the outer portions of airport approaches where, because of the large area and expense involved, acquisition of property interests may not be practical and the height limitation will probably be reasonable. It is ordinarily recommended that airport zoning be supplemented by the acquisition of fee title or easements, particularly in the inner portion of the airport approach zone, as a part of a comprehensive plan of airport approach protection.

The Federal Government has a real interest in seeing that all reasonably possible measures are taken toward the protection of airport approaches and, consequently, has actively encouraged the adoption of airport zoning, or other height limitation legislation, whenever this is deemed appropriate and effective. The Civil Aeronautics Administration has collaborated with the National Institute of Municipal Law Officers in drafting a model State Airport Zoning Act which has served as a pattern for legislation in over half of the States. Active advisory assistance is rendered by the CAA to local political subdivisions and their consultants in the drafting of appropriate zoning ordinances. The criteria of TSO-N18 are sufficiently complicated so that their translation into a zoning ordinance is somewhat difficult. CAA field personnel are available to render assistance in developing a zoning ordinance which is reasonably susceptible to interpretation by a normal, intelligent layman so that its effect upon his property can be determined without any particular, unusual investigation or the hiring of experts on his part.

Positive action is being taken by the Civil Aeronautics Administration toward protection of the approaches to those public airports developed or improved with a grant of Federal funds under the Federal-aid Airport Program. The Act itself requires the Administrator of CAA, as a condition precedent to his approval of a project, to receive assurances in writing from the project sponsor that the aerial approaches to the airport will be adequately cleared and protected by removing, lowering, relocating, marking or lighting or otherwise mitigating existing airport hazards and by preventing the establishment or creation of future hazards.

A formal commitment has been thus obtained by the CAA from all project sponsors to do what is within their powers and reasonably possible to prevent the creation of obstructions to air navigation. To date, this obligation has been assumed for the 1397 public airports developed or improved under the Federal-aid Program.

In the administration of the Federal-aid Program, the CAA has further adopted a policy of requiring a project sponsor to own, acquire, or agree to acquire, adequate property interests in the innermost portion of the runway approach with respect to all new airports or new runways developed on existing airports. The CAA has identified this innermost portion of the runway approach area as a runway clear zone; proposing that, as a minimum, the airport owner should acquire an easement in such runway clear zone. This

so-called runway clear zone is further identified as that portion of the inner approach area needed to provide 50-foot clearance between the ground surface and the protective slope of the approach surface applicable to the individual runway, as such is determined by the criteria of TSO-N18. The length of this so-called runway clear zone area is, for practical purposes, limited to 2500 feet for an instrument runway, 2000 feet for noninstrument runways on Feeder category airports or larger, and to 1000 feet on secondary runways or landing strips. The CAA further proposes that in connection with Federal-aid Airport projects for improvement to existing runways or landing strips, and in cases of certain major nonrunway airport improvements, such as terminal area development, the airport owner examine with CAA what is feasible and practical to do in the individual situation to afford positive airport approach protection.

Under the Federal-aid Airport Program, the CAA may participate in the cost of property interests acquired by public airport owners to protect airport approaches to the standards of TSO-N18. The CAA recognizes the desirability of the most positive protection possible in close-in areas adjacent to the airport and therefore has determined that acquisition of a fee interest in runway clear zone areas is eligible for Federal aid. Further, the CAA will participate in the cost of removing obstructions and in the cost of clearing the areas to the ground.

This emphasis on the innermost portion of the airport approach which is normally the most critical portion of such area, is not intended to detract from the necessity and desirability of examining the entire approach area and of doing what is reasonable to afford the most positive protection under the circumstances.

It is recognized that airports are more than instrumentalities for local transportation. They serve primarily for inter-city, inter-state and international travel. The present high level of all phases of civil air transportation and the further increases to come with the jets, emphasize the need for an adequate system of civil airports.

There is a reasonably adequate national system in being which must be continually improved and expanded. The cost of the system has been large. Heavy expenditures are called for in the future. Sound business judgment dictates that all prudent steps to perpetuate the usefulness of existing airports be taken and that new airports be so planned that they will be adequate over long periods of time.

It is submitted that the airport master plan should give consideration to ways and means of protecting airport approaches just as it does to the development of facilities on the airport proper. The airport approach situation should be periodically re-evaluated, just as the airport landing and terminal facilities should be restudied from time to time. The best time to take action to protect the airport approaches is while they are still clear. If an airport is of sufficient importance to be a part of the national system and thus is needed to support the national economy in meeting the present and future needs of civil aviation, its safety and usefulness must be perpetuated and all reasonable steps to protect its approaches should be taken.

Paper 1475 December, 1957 AT 2

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

JET TRANSPORT GROUND HANDLING[a]

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(Proc. Paper 1475)

SYNOPSIS

The variations in the ground service requirements for the new jet and turbo prop aircraft with some of the mobile equipment and fixed installations to provide this service are discussed. The interesting and unique features of some of the more radical proposals are summarized.

Some of the aspects of turbine engined aircraft ground operations which are quite different from today's operations will be examined herein.

The paper presented the problem of determining which areas of ground operations with the new turbine powered airplanes have jelled sufficiently so that they might be discussed as an industry view. Detailed examination of the problems by the airlines has shown that the matter is very complex, and the conditions at the different airports so varied that no single or simple answer can be given. The conditions which dictate one configuration or one procedure at one airport do not exist at the next where other problems become predominant.

Notwithstanding this complexity, the airlines have been studying the possibilities of various proposals for solutions to the turbine airplanes operations problems. The variations in the problems and some of the proposals that are being studied by the airlines are presented. No solutions for particular problems or specific recommendations are made.

Many of these new handling concepts and proposals would require modification to the presently available facilities and, in some cases, departures so radical that they are feasible only when considering new facilities. When the delivery schedule of the airplanes is examined, it is found that at least the first few aircraft will be in operation before any extensive modifications can possibly be completed, even if they were to be begun now. A look at the

Note: Discussion open until May 1, 1958. Paper 1475 is part of the copyrighted Journal of the Air Transport Division of the American Society of Civil Engineers, Vol. 83, No. AT 2, December, 1957.

a. Presented at The Jet Age Airport Conference, May 15-17, 1957.

1. Eng. Div., Air Transport Assn. of Am., Washington, D. C.

announced delivery schedules shows that by the end of 1958 the Comet IV will be flying in the United States, in addition to all the turbo propeller airplanes, such as the Viscount 700 and 800 series, the Bristol Britannia, the Friendship F-27, and the Lockheed Electra. Although the delivery schedule does not show it, it is rumored that the 707 is sufficiently ahead of schedule for a few to be delivered before the end of 1958, but not to be in regular service. In 1959, the 707's will be delivered in numbers, the DC-8 deliveries will begin, and the Electras by then will be flying in volume. In 1960 the Convair 880 will come into service, and the DC-8 will be delivered in volume with the 707 deliveries continuing.

The Viscount operation has indicated that there are no particular problems with their introduction into present terminals, with the exception that the fuel and electrical services vary somewhat. These will be covered later in the paper. Based on this experience, it does not appear that the Friendship, or the Electra, will be much of a problem. The Britannia, because of its size and weight, may not have unrestricted operation, but it is still smaller than the Lockheed 1649 which is about to be into service.

The jet airplanes present differences from the past operations primarily in the size and volume of the equipment and service. To allow a systematic examination of these differences and some of the proposed equipment and new concepts, a turn-around operation will be studied, and the variations noted. The operations at the terminal can be conveniently divided into the following categories, (1) the servicing of the aircraft, (2) the loading, (3) the engine starting, and (4) the movement of the aircraft in the terminal area and on the airport. Many of these are interrelated and some of the systems or concepts proposed embrace all categories.

The Servicing of the Airplane

The most time-consuming service item is that of refueling. With turbine engine aircraft, of course, the amounts of fuel consumed are considerably greater. The fuel capacities of the various aircraft to be operated in numbers in the United States are as follows:

> The DC-8 and 707 have capacities varying from 15,500 to 23,500 gallons depending upon the particular model.
>
> The Convair 880 and the Comet IV carry about 10,500 gallons.
>
> The Electra, Viscounts and Friendship are 5,360, 2,300 and 950 gallons, respectively.

One should note that the turbo prop airplanes, i.e., Electra, Viscount and Friendship, are all within the range of present piston aircraft which have capacities up to 5,500 and 6,500 gallons. The jet aircraft, however, hold up to four times as much fuel as the larger piston aircraft. However, it is not necessary to supply the full load of fuel under normal operations because the reserve fuel always remains in the tank. A rough approximation of the amount of fuel consumed over various stage lengths appropriate to the aircraft give an idea of the amount of fuel that must be boarded.

The 707 and DC-8 would consume approximately 5,900 gallons on a 1,000 mile trip and about 13,300 gallons for a 3,000 mile trip. The Convair 880 would utilize approximately 4,400 gallons for 1,000 miles and 8,200 gallons for 2,000 miles, and the Comet IV about 10% less. The Viscount and Electra would use 360 and 600 for a 200 mile trip, respectively, increasing to 1,400

and 2,000 for a 1,000 mile leg. The Friendship fuel utilization for 200 miles is 220 gallons.

The largest of the fuel trucks presently utilized for aviation gasoline are just slightly over 5,000 gallons capacity; modifications of these fully loaded would suffice for the turbo prop airplanes. However, for the turbo jets the fueling becomes more of a problem. The amounts of fuel require three, and in some cases four, truck loads of fuel.

The ATA Working Group on Fuel Servicing & Equipment is now formulating new requirements for trucks of the 7,000 to 8,000 gallon class specifically for turbine fuel. These will be the types used when the large jets first come into service.

Other than the greater size and the greater number of axles to carry the loads,these fuel trucks will incorporate sizeable water separators and filter units which are necessary to assure clean dry fuel being pumped into the aircraft. JP-4 and kerosene both have a greater affinity for water than aviation gasoline and the suspended water does not settle out as rapidly.

Where more than two trucks are required for a fueling operation or where the volume of fuel dispensed is high, the installation of an underground fixed fueling facility should be considered. The problems at each location are different, particularly concerning future expansion. One thing is important, however; when the airplane is connected to the fixed ground system it becomes a part of the system and must be considered in the design particularly with respect to the fueling pressures, rate, and surge control.

When the fueling is accomplished by a fixed ground hydrant system, a hydrant cart between the fixed system and the airplane will be utilized to carry the necessary hoses, fuel meters and the larger filter/water separator units. These will be somewhat larger than the small units, such as those at Amon Carter Field, primarily because of the filter/separator unit. Indications are they can be mounted on a 1 or 1 1/2 truck chassis.

One of the significant features of the new turbine airplanes is the underwing fueling provision. The Electra is unique among the group in providing single point underwing refueling for all tanks. At a fueling rate of 300 gallons per minute, the fuel for the longer flights of 2,000 miles could be loaded in a matter of less than 12 minutes from the time the truck drives into position until it leaves.

The 707, DC-8, and 880, however, all have four underwing refueling points. In the standard configuration these are located two on each side between the nacelles. Hoses are connected to each fill point from a truck which would be located in position almost between the nacelles. Each hose is capable of delivering fuel into the airplane at a rate of at least 300 gallons per minute, and in the case of 707 at somewhat over 350 gallons per minute for a total of about 1,500 gallons per minute. One airline has a special configuration whereby the two fill points on each side are located outboard of the engine pods near the trailing edge of the wing. This location allows the fueling vehicles to be driven under the wing and reduce the interference with passenger loading traffic forward of the wing.

The ATA Working Group on Fuel Servicing & Equipment has been working with the American Petroleum Institute-Aviation Technical Services Committee to set forth design recommendations on fuel trucks for both aviation gasoline and turbine fuel. In the immediate future this group will prepare similar reports covering hydrant system dispensing vehicles and the desirable safety features to be included in hydrant systems.

In addition to the fuel there is the requirement for engine water.

In the jets only the DC-8 and 707 models with J-57 engines will require water for takeoff power augmentation. This engine requires chemically pure water with no more than 50 parts per million impurities of dissolved solids in order to prevent the buildup of scale on the compressor blades and the consequent reduction in power of the engine. One of the advanced model J-57 engines may require the water to be demineralized to 5 parts per million. This water will be completely utilized during takeoff. At temperatures above 40°F the tanks will be completely filled. Between 20° and 40°F the tanks will be filled half way and below 20° none is utilized. After takeoff the water tank and system is purged and dried out to prevent freezing at high altitudes. The problem of keeping the water from freezing on the ground is being investigated. As far as the airplane system is concerned, it appears that due to the length of time for the water to freeze no flight problem will be encountered if the water tanks are filled just prior to takeoff time with water that is somewhat above the freezing point. However, this is being checked by the manufacturers. Up to 705 gallons will be required for each takeoff. This will be pumped into the aircraft at rates up to 100 gallons per minute. Special trucks will be utilized in most instances to service the airplane with this water, although at least one operator has indicated plans to pipe the water directly to the ramp area with a small demineralizer cart purifying the water before it is pumped into the airplane.

Galley service will be relatively unchanged from present practice except that the galleys have separate entrances on the opposite side of the airplane from the passenger loading doors which will allow simultaneous passenger and galley loading. Considerable improvement in galley service by combining the individual galley packages has been made with present aircraft recently and the service procedures should continue improving.

The air conditioning systems vary, depending upon the operator. Some are planning on the use of conventional ground air conditioning trucks while others have self-contained systems which are operated on the ground by electrical power supplied by ground electrical units.

The electrical systems on the United States aircraft all utilize 115/200 volt, 400 cycle A.C. power. Depending on the configuration of the airplane and the decision as to whether the air conditioning system will be operated at a particular station, ground power units with ratings of 37.5, 60, 90, or 125 KVA will be utilized.

The methods and requirements for the supply of ground electrical power could be a subject for a complete paper. Recent meetings of the ATA Ground Equipment & Maintenance Facilities Subcommittees have had detailed analyses of the requirements for mobile and fixed electrical installations presented to it.

The European aircraft have varying requirements. The Vickers Viscount and the Friendship both utilize the 28.5 volt D.C. system. The engine requires 1,400-1,500 amperes for 1 - 2 seconds during the starting procedure after which the current drops off rapidly. A 1,500 ampere power unit should be able to handle the load. The Britannia and the Comet both have dual bus systems supplying 28.5 volts and 112 volts. The peak requirements for the Comet IV, which is the more critical of the two, will go up to 700 amps at 112 volts and 1,400 amps at 28.5 volts.

The Loading

With respect to baggage and cargo loading, some new innovations are being introduced. Plans are now being finalized by some airlines to incorporate cargo containers into the cargo hold which will be removable such that the container will be preloaded in the baggage room, hauled out to the airplane in a baggage train, and hoisted into the cargo compartment. This system will eliminate the multiple baggage handling which contributes so much to the baggage damage experienced today. It will also eliminate the "bucket brigade" system for the loading of cargo compartments and should materially assist in speeding up the baggage delivery. The containers would hold up to 40 pieces of average luggage depending upon the airplane.

When the first jet services are introduced the passenger loading will be handled by conventional mobile passenger loading stands at both front and rear passenger doors. Due to the larger size airplane and higher door sill level, up to 162 inches, the stands will be larger than the present ones. The present ones are now near the limit for hand propelled stands, consequently, several possibilities for using powered stands are being tested and used. One version utilizes conventional appearing stands which are battery powered. The batteries are recharged by trickle chargers at the stand parking location. Another version has the stand mounted on a light pickup truck chassis. Both versions have been successful and will be utilized.

The discussion of passenger, baggage and cargo handling would not be considered complete without the inclusion of some of the systems which have been proposed. In new facilities these, or variations of these, may find considerable advantage and each should be studied in detail before a new facility is planned. One of the first systems was the Whiting Loadair which utilized the principle of parking the aircraft on mobile trucks on a rail system which was imbedded in the ramp and which moved the aircraft laterally into position against a fixed finger. This finger had passenger loading on the upper level and baggage and cargo belt conveyors on the lower level. It also permitted precise positioning of the airplane which allows fixed installations in the ramp for other services such as fuel, electricity, air conditioning and the like. A prototype was installed on one gate at the Idlewild Terminal for one year's trial. Applications of this principle are very useful in pure cargo operations and will be used in some major cargo stations.

The Lockheed Aerobridge and the O'Hare Gangplank were the first versions of the moveable, telescoping covered walkway for passengers. These involved passenger handling on the second level in the terminal with the walkway leading to the door of the aircraft which was parked parallel to the face of the finger. Variations of this principle are being proposed as parts of new terminals.

The United Airlines airdock was a concept examined for present piston powered airplanes in which the entrance is on the left rear behind the main wing. In this system the airplane was backed into a dock from which a short extendable covered gangway projected to the passenger door location. All the fixed facilities for baggage, fueling, electricity, etc., could easily be located as with the Whiting system. The new aircraft on order from the United States manufacturers all feature a loading door forward of the wing on the left hand side. Such a location would permit nose in positioning of the aircraft and would, obviously, make such an installation more feasible. The recent ATA Ground Equipment meeting, previously mentioned, heard proposals of this nature from a representative of the Douglas Company. The obvious advantage of completely removing the passenger from contact with the ramp and protecting him from the weather needs no discussion. Other advantages are the

reduction in loading time and the ability to continue loading the passengers even though the engines are being started.

The considerations of such installations are very complex and should be studied in every respect from the economic and utilization aspects to flexibility for the future expansion and aircraft development.

The Engine Starting

Returning to the discussion of the introductory operations, the aircraft is now loaded and ready for departure. The engines are ready for starting. At this point a new service is necessary—air supply for engine starting. The requirements of the operators differ here as in the electrical supply. The starting systems vary from airline to airline depending upon whether the aircraft is space limited or weight limited on the particular routes. Some airplanes will operate with integral air supply for engine starting, others utilize a smaller integral system for emergency operation at off line stations with the main air source normally being supplied by mobile or fixed systems at the airport. There are also differences in the ground pneumatic power systems in that some airlines will utilize high pressure air with a combustor unit to heat the air while others will use low pressure air with combustor units. The flow rates and the temperature of the delivered air are a compromise with the required time interval for the engine start and the service life desired from the combustor units. In general, however, flows will be required to start the engine in 20 - 30 seconds. As an example of the airflow required, the J-75 would require about 120 #/min. at 53 psi while the other engines are less. The Allison 501-D-13 on the Electra for instance requires about 80 #/min. at 40 - 60 psi. The starting unit is electrically connected to the airplane so that the crew controls the engine start. Both the high pressure bottle cart and the low pressure tank must be recharged. The low pressure system can be charged from present fixed systems supplying shop air, but the high pressure system will require special compressors. At least one development combines a low pressure tank and combustor unit on a truck chassis with a compressor attached to the transmission power take-off so that it is a completely self-sufficient unit.

When fixed facilities are being installed in the ramp, consideration should be given to the provisions of a fixed pneumatic system with its required storage tank. Several manufacturers utilize such systems on their flight line and runup areas and have found them to be very economical and maintenance free. Particular attention should be given in sizing the tanks and compressor in fixed systems to provide for peak starting frequencies without depleting the air storage. This depends also on the procedure to be used in starting; in other words, does the operator plan to start only one engine from the ground system and then start the other three engines from cross bleed air from the operating engine compressor or would all four engines be started from the ground system.

With the operations of the engines on the ramp, attention should be given several points. One is ramp cleanliness. The Air Force experience with jet engines has stressed the seriousness of the ingestion of foreign objects into the engine inlet. This is the greatest single cause of jet engine failures. Although the result of operation of similar podded engine configurations is better than the average, it is still significant. With the engine operating at low power as in the gate area, the vacuum cleaner effect at the engine inlet should not be sufficient to suck bolts or pebbles off the ground, but particles borne by

the wind or kicked up by passing airplane prop wash may enter the inlet area and cause severe failure of the engine compressor section. The turbo props, however, have the centrifugal action of the propeller to deflect any entering particles and will not be affected.

Several large vacuum type sweepers have been developed for the Air Force and could be available for commercial use. These units are capable of sweeping one million square feet per hour and travel at about 20 miles per hour. This particular type because of its size may not be feasible for cleaning ramp areas, but may be useful on large fields for taxi-way and runway sweeping, should that prove to be a necessity.

With the engines idling, the remainder of the ramp equipment such as electrical, air conditioning and ground pneumatic units are disconnected and removed from the area. The engine thrust on the side nearest the terminal is advanced slightly for a short period to produce the necessary breakaway power, and the aircraft, steered by the captain, is turned and taxied away in a normal fashion with just slightly above idling power. Since the engines burn up to 10.25 gallons per minute in idling, it is imperative that the ATC clearance be obtained before leaving the gate. The aircraft would be taxied directly to the takeoff runway, since there is no pre-takeoff runup. Whatever checks on the engine operation are necessary are made during the first seconds of takeoff power.

In the terminal area much thought has been given to the consequences of the engine exhaust velocity, temperature and fumes. The engine will only be operated at low powers in the immediate terminal area, and, therefore, the problems are minimized. The temperature doesn't appear to be a problem since the exhaust would blow anyone out of the way before he could get into a high temperature area and be burned. The fumes are only a minor problem. Caution should be taken to locate the air conditioning inlet remote from the gate positions to minimize the possibility of the fumes entering the system. The exhaust velocity aft of the tail of the aircraft will be somewhat higher than present piston aircraft, but it is more localized in nature. The velocities, of course, are a function of the distance from the tail pipe, but even for a wing tip clearance of 20 feet the velocity would have no effect on permanent type buildings, or on the ramp equipment, provided the brakes were set. The public and unnecessary ground personnel could be restricted from the gate area to minimize the exhaust annoyance. If, however, the gate configuration and spacing are such that the exhaust interferes with operations at adjacent gates, simple gate separating fences can be positioned between the gates to deflect the blast upward. Such fences can be constructed of standard plywood panels with a flat inclined face and should be 6 to 7 feet high. Glass or Plexiglas panels can be built into the fence to provide visibility between gates and to prevent accidents with ground equipment moving within the area or between gates. The fences are low enough that the airplane outboard wings can clear the fence, and, therefore, would not increase the required gate size. Similar devices could be used where protection of passenger walkways is required or observation decks are adversely affected.

These inclined fences also have other advantages in minimizing the noise in the terminal area. This may not be a problem at some stations, or at some gates where there is plenty of space or where the finger configuration provides partial protection such as at the end of the finger. It should be noted that the noise in the terminal area will be different in character from the flight noise in that the major noise is high frequency noise from the

compressor inlet. Fortunately, this noise frequency band is rapidly attenuated by passage through the air and is also easily reflected from flat hard surfaces. Therefore, any gate separating fence would also reflect a large portion of the noise and make the area beyond the fence more pleasant.

It should be noted also that this noise would not create problems inside the terminals or fingers provided it is tightly enclosed and the doors or windows are tight. This has been substantiated by tests by the Boeing Company and surveys during jet operation at San Francisco by Douglas.

The noise problem is also abated by keeping the passenger out of the gate area and in the terminal or finger. Only essential ground handlers need be in the gate area and these would wear ear muffs or helmets for noise protection.

Where the space is available for parking the airplane further from the finger (up to 70 feet) even these simple protection features may not be required. In any event the problems at each particular gate position should be carefully weighed and consultations with affected airlines should be held before any particular solution is proposed.

The Movement of the Aircraft in the Terminal Area and on the Airport

The maneuverability of the large jets has been given particular attention by the manufacturers. The turning radii of the domestic versions has been kept to 101' for the 707 and 90' 10" for the DC-8, while the intercontinental 707 turning radius is up to 108' . The domestic versions can, therefore, taxi into the same gate positions as the large Lockheeds 1649 and 1049. Since it would not be normal to be maneuvering aircraft in adjacent positions at the same time, gate size of 180' between centers will probably be satisfactory for the domestic airplanes. There is no technical problem connected with their maneuvering as close as 20 feet to the finger although as pointed out earlier, close supervision of the personnel and passengers may be required to keep them out of the area. In general there is no serious problem in taxiing these aircraft into the gate position as is done today. The first operations will be limited in number and may be given special consideration in the selection of the most suitable gates. From this early experience the problems with volume operation can be more readily evaluated.

Some of the aircraft handling concepts which were discussed earlier would require some type of towing device to move the aircraft backward out of the nose in the loading dock. Many such devices were proposed when it was thought that the jet operation would require extensive towing in operation. Such devices may have application in that it should be possible to build them cheaper than a large conventional tow tractor. Due to the development time required for these, however, it appears that large conventional tow-tractors will be utilized at least during the initial operations for towing to and from the maintenance area and where necessary for backing the aircraft out of the gate. These units will weigh up to 40,000 lbs., will provide up to 25,000 lbs. draw bar pull, which is what is required on sloping and/or slippery ramps. Towing will be at speeds of 5 to 10 miles per hour depending upon whether the airplane is fueled or not. Small electrical generators will be mounted on the tractor to provide energy for operation of the airplane brakes. In the operation at the gate, however, the engines will be running and the auxiliary power will not be required.

The radical type towing devices are interesting, and since they may ultimately find use they would bear some discussion. Each of these devices utilizes the principle of taking advantage of the airplanes weight to provide

the traction rather than building the weight into a tractor unit. One device proposed picks up the nose gear of the airplane and is driven in that position as the tractor unit on a trailer truck. Three others utilize methods of powering one or more of the wheels on the aircraft main gear trucks. The unit developed by the Consolidated Diesel Electric Corporation uses hydraulic power to drive a hydraulic motor which is attached to one wheel of each main gear. The controls are connected electrically to the pilot's compartment and the pilot actually drives the airplane. The ground power unit is driven along under the belly of the airplane. Another type proposed by the Air Logistics Corporation involves driving wheels being forced against the main airplane tires using the friction force between to turn the main wheel. In this system only one main gear would be powered.

A third type proposed by Bloomquist, a Consulting Engineer, would power the main wheels by a chain drive device.

In a general fashion the procedures and some of the equipment which will be utilized during the first jet operations have been outlined. It should be reiterated that although most of the paper has dealt with the large jets, the turbo prop airplanes will operate into more and smaller fields. These will present no special handling problems.

The various pieces of ground equipment and the possibilities for building fixed installations were mentioned but since the technical details of each system would lengthen the paper considerably, it was not possible to include them. Each airport presents different problems in fixed installations and the requirements of various airlines differ. Therefore, a study could be made to apply only to one airport. The system of direct contact between the airport operator and the airline is the only feasible way to finalize the requirements for a particular location.

Paper 1476 December, 1957 AT 2

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

AIRPORTS, PLANES AND PEOPLE[a]

William L. Pereira[1]
(Proc. Paper 1476)

SYNOPSIS

The purpose of the Jet Age airport and passenger is yet to be fully recognized. The master planner and the entire air industry must design today a dynamic, integrated ground complex whose purpose is accommodating the planes and the passengers of tomorrow's jet air travel.

At this very moment, history is classifying mankind in an age—the Jet Air Age. All that history will record about this age is up to mankind, inferring a responsibility completely unique to our time and absolutely staggering with importance. It offers, as has every other age, an imposing challenge: Will it benefit man? The attempt to answer this question has drawn men from all segments of the air industry together. All are specialists in their fields; none of them master of it all. To achieve some whole measure of benefit for the future, it is for them to discover very soon a common way to the same end, and to begin their achievement with the lessons of history and the fundamentals of the present.

Man since his beginning has had an insatiable appetite to make more and better use of his time on earth, and among men there has always been a percentage which has sought not to imitate themselves, but to seek new horizons and once having arrived there to learn what was beyond. Both of these compulsions have been truths since the day man became discontent with himself as a means of propulsion, threw himself on the back of a less intelligent but much fleeter animal, and so commenced his conquest of Time. When both man and the animal were obstructed by a body of water, he used his intelligence again and found the means to float upon its surface; crudely at first, then, with greater and greater skill, he began his conquest of Distance.

Note: Discussion open until May 1, 1958. Paper 1476 is part of the copyrighted Journal of the Air Transport Division of the American Society of Civil Engineers, Vol. 83, No. AT 2, December, 1957.

a. Paper prepared for presentation at Jet Age Airport Conference, New York, N. Y., May, 1957.

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Several hundred years ago, giants like da Vinci conceived the basic principles of flight, and not so long ago the missing link in the conquest of space—the airborne engine—came into being. Where before it took hundreds, even thousands of years to progress on a universal basis with a device invented by man to move himself, today it takes a few months or years. In effect, we are realizing our future now almost as fast as we can visualize it. Man has conquered time and distance and has become civilized, and persists now in a quest to conquer space, as well.

The speed with which the Air Age arrives at its various plateaus is truly remarkable when compared with the history of the development of other means to transport man, and one wonders from where does the Air Age receive its enormous energy for its scores of accomplishments. It seems conclusive that this energy and its products are fantastically accelerated by the fact that the world in two generations has endured two world wars and has before it the threat of a third. The great industrial and scientific efforts in the conquest of space are rooted in the determination to seek and find superior weapons. In the backwash of the weapons development, almost incidentally, have emerged the residuals, shorn of their fangs and available for the peaceful pursuits of man.

It appears to be man's fate, therefore, to propel himself toward his destiny by means of the residue from his inventions for destruction. Immeasurable benefits to peace resulted from a need to invent gunpowder, and certainly an enormous impetus to medical progress has always come from the necessity to experiment medically with huge quantities of human wreckage during and as an aftermath to battle. Today we use the term "Cold War" and, in fact, have developed and even abandoned many weapons before testing them in battle. Man has perhaps advanced, then, to a point where the threat need merely be posed to develop bigger and better means of retaliation and defense. In any event, he is about to benefit in peace from the development of the high speed, long range, jet propelled bomber for war—the prototype of the new passenger plane, which in the year 1960 will take its place in the history of transportation. The Jet Air Age commences.

Correlative to the existence and availability of this airplane for practical flight is the very large question of its adaptability to existing ground facilities and their counterpart, systems of air control. Obviously, in the days of small planes and low speeds there were relatively small problems; when air transportation involved one plane a day, one or two passengers a day, and a runway in a beanpatch, the science of ground design could indeed be primitive. That it remained in a primitive state through the years of real need for change has caught up to the present with a vengeance. A few years ago, the industry's concern with design was limited to accepting a few static design principles which were then completely set aside from researching for the needs of the future. The fundamental that as the plane changed and grew in kind and number, ground design must necessarily allow for the change was fundamental in theory only; selecting real estate, therefore, or in other ways preparing for the future was considered whimsical, if it was considered at all. The fact was then and still remains that the planes in our future should unquestionably determine the design of our airports and air control systems now.

Now this fact is accepted and believed. Even so, the cities and the counties continue to make their own adaptations, "expertly" and politically. Each governmental agency in its own particular regime and within its limited scope

makes belated rules and attempts to establish palatable controls. Each airline, cut into several parts by the specialists within it, treads water in a maze of economics, regulations and statistics; caught halfway between approving progress and fearing it. We have all done very badly in the airport field since it began—the professions, the airlines, and the local and federal governments. This is partly because no one element recognized what all the others have had to offer, and mostly because each has concentrated on parts to the whole—an airway, an airplane, an airport—rather than seeing the reason for all three—service to man—and integrating the elements accordingly. Had the reason been recognized, the acceptance of air travel as fulfilling a human need might have been accurately predicted. Not having been recognized, the error of making plans too small, and even those too late, persists. The American airplane and the American airline is the standard for the world; the American airport, with very few exceptions, is an accident waiting for a place to happen.

Consider that the most vital Air Age element of all—the passenger—is yet to be agreed upon. Some airlines regard him as a midget; others as a giant. Some tolerate him; others cater to him. Some believe he should be informed; others please to keep him mystified. Air planners refuse to see that the Air Age is meant to benefit people, to accommodate their pleasures, their education, and their personal needs. It is a too limited interpretation which says that air travel is predominantly an opportunity for business enterprise.

We are very slow to learn. Our new airports are still planned with old attitudes and talents; the same interests that failed in the past are recalled for still more advice: and the results are the same static conception of airports as being merely bases for airplanes, and the same inadequate, inaccessible locations for them being made available by the local government. What airports are really meant to be and how they should best serve continues to elude us; and not for the reason that responsible agents have been ignored. All of the specialists have had their say, and mostly at the proper time. In brief, the opportunities have existed, but the foresight has not, to take the Air Age for what it really is—a gigantic evolution in the habits of man—and to plan for it being just as practical as it is imaginative.

To what will the problem yield? To the art and science of creative master planning, which somehow must take the reins from what behaves for too many now as the end-all: awkward, arrogant statistics and logistics that have become the quicksand of their efforts. The problems will remain and multiply as long as numbers of passengers are tallied instead of reasons for the passenger's existence. The time could not be more right for realistic, imaginative master planning; planning that will provide for flux and growth and change, which are the inherent, most elementary characteristics of airports to come. This planning will not attempt to solve all problems permanently, but will, rather, envision that the problems must be dealt with constantly. Therein lies a lesson for us all: we cannot write the whole book; we must be content to contribute chapters to it, making very sure that all the parts are valid, integral and beneficial to the whole.

How will the master planner see the problem? He will first see that we are moving people; people who are not compelled to fly, but who do so for their particular reasons. He will understand that the passenger is not a mechanical man fastened to a complicated ticket, and that his motivation to fly did not begin at the ticket counter, but in his home or at his office. He will consider that the plane trip involves getting from home or office to a destination and back, and that time within the airport and to and from the airport must be

taken into account with efficient methods of disbursing and receiving, and high speed ground transportation. What good are the present and attainable jet air speeds when it takes 50 minutes to get to the airport and another 20 minutes to be processed through it? What justification is there for flying from Los Angeles to New York in 3-1/2 hours only to spend another 1-1/2 hours reaching the ultimate destination? He will recognize that people fly to save valuable time and that the obstacle course of waiting lines and walking distances must be replaced by efficient means of assistance to the passenger in making the smoothest, fastest transition possible from ground to air and back. He will illustrate the airfield complex not merely as a maze of runways and taxi-ways joined to the terminal by an unsolved expanse of concrete, but as a tremendously responsible and related accommodation to people on the ground and the planes in the air. The master planner will start with the idea of furthering man's desire to hoard time and cover greater distances. He will by training and instinct consider with equity the past and present, and will be judged according to the scope of his vision of the future. Only on this broad basis can the ground catch up to the air.

To more specifically point up the present Jet Age airport problem is to describe in part some resolutions to the problem. Currently on the boards in a state of expansion metamorphosis are the Los Angeles International Airport facilities (Fig. 1). The design concept accommodates the two basic airport functions: aircraft circulation on and above the ground; and passenger circulation outside of and within the terminal. It is the decentralized or "satellite" plan and is characteristic of no other airport in existence.

This plan permits to the flow of aircraft traffic on the ramps and taxiways easy adaptation to the design configuration of parallel runways in a unidirectional system disposed around a central terminal area. The design provides one pair of runways for landings and a different pair for take-offs, made possible by the local meteorological conditions. Studies of prevailing wind direction and of actual runway usage covering a number of years indicate that more than 95% of landings and take-offs are made from either west or east, and more than 85% from the east alone. By aligning all of the primary runways in the favored E-W direction, therefore, and by designating one pair for landings and another for take-offs, it is feasible to effect maximum area utilization. This greatly expedites the handling of departing and arriving aircraft, and provides an additional safety factor in that the two types are kept widely separated. Under normal conditions, the general circulation of aircraft traffic around the perimeter of the ramp area and on adjacent taxiways is always to the right in a clockwise direction. This reduces the possibility of conflict caused by two aircraft crossing courses or meeting head-on, makes for an orderly, easily controlled flow of traffic, and delays in ground traffic are reduced to a minimum (Fig. 2).

In the broadest sense, a terminal is the functional link between ground and air. It must accept all sorts and types of undisciplined streams of passengers, visitors, baggage, freight, express, vehicles and aircraft which, before the terminal can be called efficient, must be directed into specific channels tailored to satisfy the particular requirements involved. Early in the design stages of this project, it was determined that the final design concept would be dictated almost entirely by functional requirements; the result was the "satellite" plan, which accommodates with maximum efficiency both passenger and airline. The passenger arrives directly at a given airline's ticketing building; his ticket and baggage are processed; and he reaches that airline's plane

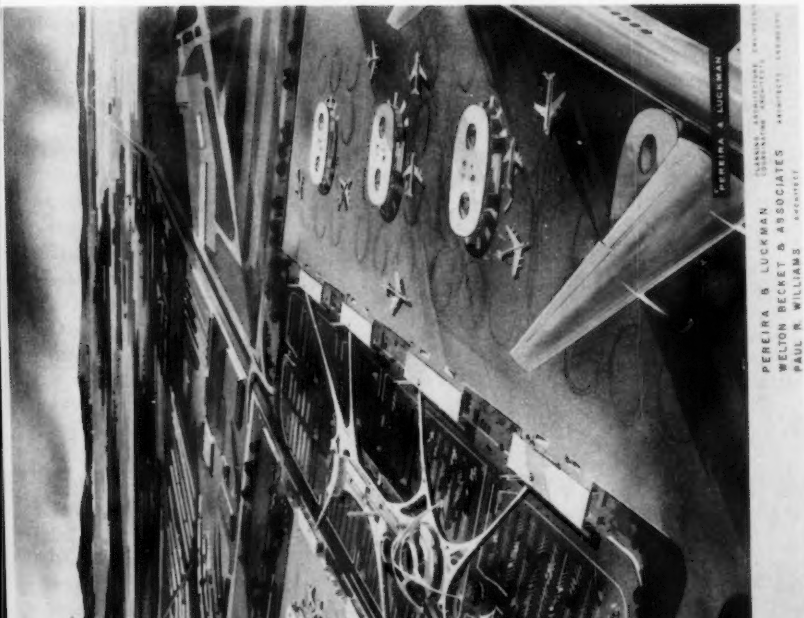
LOS ANGELES INTERNATIONAL AIRPORT
PEREIRA & LUCKMAN
WELTON BECKET & ASSOCIATES
PAUL R. WILLIAMS
PEREIRA & LUCKMAN

Fig. 1

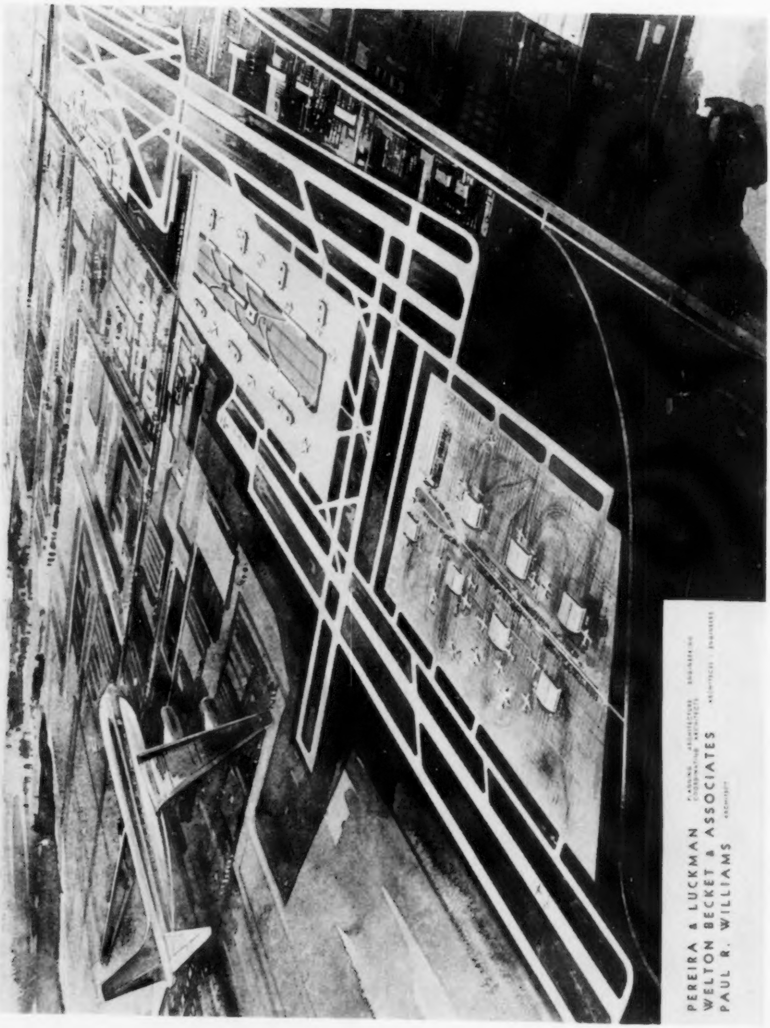

Fig. 2

loading ramps by direct and separate channel access from that building to the ramps. This permits individual, independent operation for any given airline, and direct, unencumbered departure and take-off for the passenger (Fig. 3). The economic advantage is obviously great; a means of orderly expansion of the components is provided, and components are constructed only as required which avoids the possibility of "over-building."

Of primary importance in the very beginning stages of the plan was developing realistic forecasts of passenger and air traffic volume expected by 1965—the date around which the design is based. Intensive studies determined the over-all space requirements for airline passenger and operations buildings; the type and extent of concessions facilities; the need for and scope of government quarters; the amount and location of automobile parking space; and the various facilities required for non-aeronautical public services. A forecast was made, too, that the size and number of communities within the greater Los Angeles metropolitan area would create an impetus for use of helicopters to service the airport; and a method of transporting people by helicopter from smaller, outlying airports to the various airline satellites within Los Angeles International was reviewed and incorporated into the plan.

That, in brief, is Los Angeles International. But neither this airport, nor any of those now on the boards will write the last chapter in ground facilities for the instruments to come which will satisfy man's craving to conquer space. Los Angeles International may be the last of the airports which are there because the cities were there. The next chapter will be written of something bigger—of the dawning of the "air harbor."

For out of the Jet Age is sure to come a whole new and impressive aspect to air transportation—global flight. With its advent there must surely come something which the term Air Harbor might best describe; harbors for rockets, missiles, and for aircraft now on the boards which are hampered and restricted by today's airports; harbors for craft capable of flying at incredible speeds, to where and from where we can only imagine.

Airports today are a result of the location of our cities, which means that where they are does not necessarily presuppose weather, proximity and accessibility. The Air Harbor will be where Nature and the enormity of things to come determine. Then, around it—possibly under it—a city will grow. There will not be many of them, but they may very possibly involve hundreds of square miles of space. Our airports of today will feed them.

Where will they be? Well, where since the beginning of civilized man have our cities been? First along the rivers; then flanking the oceans from continent to continent. What did the mariner seek as he probed through the ocean approaches: a piece of the area that nature had endowed with the protection of the land—a harbor—else he could not land. Those who followed him made a port on the land within the harbor, and around it a city grew. From this city went the life and the commerce and the culture to create other cities. Nature located the sea harbor; and Nature may select as a place for the coming air harbor a vast expanse of desert, or some other similarly undeveloped source of space. She may select it because it is the only natural, practical, justifiable place to accommodate the air harbor's demands.

One day, the air age will reach its own zenith. It will create its own cities and, in effect, epitomize the change in the habits of man. We cannot collapse time and distance as we intend to do without leaving a new mark on the land.


5
UNITED
LOS ANGELES INTERNATIONAL AIRPORT
PEREIRA & LUCKMAN
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PAUL R. WILLIAMS

Fig. 3

Paper 1477 December, 1957 AT 2

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

A STATISTICAL APPROACH TO RUNWAY LENGTH[a]

Ralph T. Glasson[1]
(Proc. Paper 1477)

ABSTRACT

These notes discuss the statistical nature of variables affecting takeoff runway length. Effect of variation in payload, climatological factors, and airplane performance is covered. The need for individual analysis of each airport is stressed. The method was derived for United Air Lines' DC-8s, but is applicable to other aircraft.

During the A.S.C.E. Jet Age Airport Conference, the manufacturers of large turbojet powered aircraft presented considerable information on both the benefits and problems associated with the introduction of these craft into commercial airline service. Among the problems confronting the airport operator and designer is the determination of adequate runway lengths. Generalized curves of Takeoff & Landing Runway Length Requirements are available from the aircraft manufacturers.

Generalized information on runway lengths can be very misleading. United Air Lines feels that requirements at each airport must be studied individually to obtain results which are mutually satisfactory to the airline operator, the airport management, and to the travelling public.

In order to provide a common basis for discussion between ourselves and the airports into which we contemplate early operation of the DC-8, we have prepared a report detailing United Air Lines' DC-8 Airport Requirements. This document has been furnished to airport officials at major cities served by United Air Lines.

Note: Discussion open until May 1, 1958. Paper 1477 is part of the copyrighted Journal of the Air Transport Division of the American Society of Civil Engineers, Vol. 83, No. AT 2, December, 1957.

a. Paper prepared for presentation at Jet Age Airport Conference, New York, N. Y., May, 1957.

1. Eng. Dept., United Air Lines, Inc., San Francisco, Calif.

United Air Lines' study of DC-8 Airport Requirements considers: (a) General operating characteristics of long range turbo jet aircraft; (b) Runway length, width, and orientation; (c) Runway and taxiway load bearing capacity; (d) Taxiway width and form; (e) Ramp maneuvering space; and (f) Nuisance abatement.

The purpose of the study is to: (1) Assemble in one document physical dimensions and data necessary for planning purposes; (2) Outline potential problem areas; (3) Present and substantiate DC-8 runway requirements at the major airports served by United Air Lines; (4) Present minimum requirements; and (5) Avoid detailing the manner of accomplishment. This is a proper function of airport engineers and planning consultants. For example United Air Lines does not wish to specify concrete or asphalt pavement. The report specifies tire pressures, weights, etc. and areas in which fuel spillage may occur. The pavement design is considered beyond the scope of our report.

The balance of this discussion is confined to the method employed by United Air Lines to determine runway lengths required for DC-8 operation.

A need exists for analytic evaluation of runway length requirements. United undertook a study to devise this method for several reasons:

1. Many requests have been received from airport managers and engineers for United Air Lines' requirements.
2. Conflicting sources of information are available:
   (a) CAA publication T.S.O. N6A.
   (b) Manufacturers' publicity releases.
   (c) Manufacturers' airport requirements studies.
   (d) Articles in trade and professional journals.
3. Economics must be considered.
   (a) Construction costs are high.
   (b) It is probable that costs will be passed on to airlines through increased landing fees, fuel taxes, etc.
   (c) An economic balance between payload restriction and the cost of runway construction must be determined.

It is considered unreasonable to expect runways long enough to permit carriage of full payload under the most adverse combination of conditions.

An example of adverse conditions would be: (a) Longest trip segment; (b) Lowest powered aircraft; (c) High fuel reserve; (d) High speed cruise; (e) High headwind; (f) High temperature at takeoff; and (g) Capacity payload.

Such conditions would define a runway which would seldom be required in actual airline operation. This demonstrates the need for a more thorough approach.

What factors must be considered in determination of necessary runway lengths? Following is a list of those factors considered in the United Air Lines' study: (1) Civil Air Regulations; (2) Airport elevation; (3) Airport obstructions; (4) Runway gradient; (5) Stage or trip length; (6) Weight (empty) of aircraft; (7) Airplane performance characteristics; (8) Engine performance characteristics; (9) Reserve fuel policy; (10) Passenger seating configuration; (11) Cruise control procedures; (12) Altitudes to be flown; (13) Seasonal variations; (14) Probable departure times; (15) Surface temperature; (16) Surface winds; (17) Enroute temperature; (18) Enroute wind; (19) Available payload; (20) Nuisance abatement; and (21) Performance sacrifices to noise suppression devices.

How do we combine these variables? The problem is probabilistic in nature. The desired result is a statistical distribution which shows the

likelihood of encountering a restriction on the available payload. Such a distribution is shown in Figure 1. It should be emphasized that this concept contemplates the actual off-loading of payload which is at the airport and available to be carried. Variability in available payload is considered.

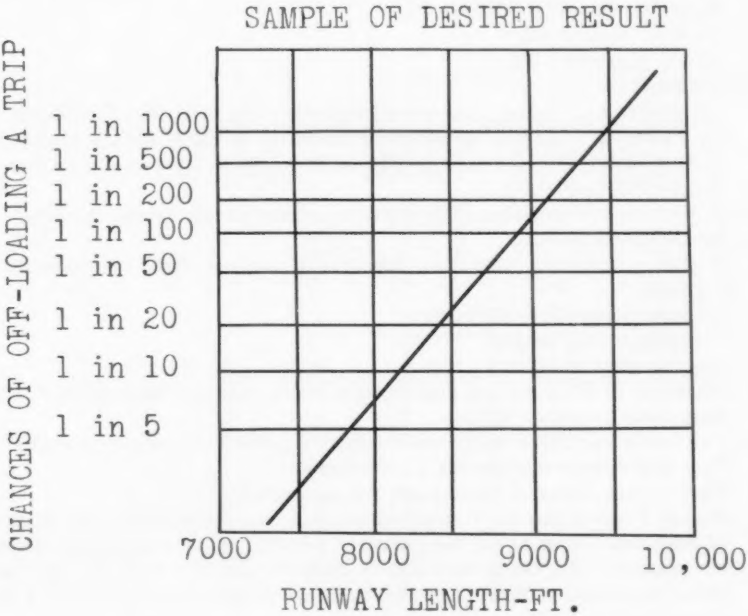


Figure 1

Some factors are considered constant for the analysis of a given airport:

1. Airport physical characteristics:
   Airport elevation
   Existing runway gradient
   Obstructions of permanent nature
   Obvious physical limitations
2. Policy areas:
   Civil Air Regulation performance requirements: Air-worthiness requirements for turbine powered aircraft have not been finalized. This study assumes the "equivalent safety" proposal made by the joint panel of the AIA and ATA.
   Reserve fuel policy: Reserve fuel is that required to specify a 300 nautical mile alternate including climb, descent, and 15 minutes holding fuel, in addition to the current CAR requirement of 45 minutes cruising fuel.
   Cruise altitude: Cruise altitude is assumed to be 35,000 ft. When 35,000 ft. altitude is unattainable due to thrust limitations, 30,000 ft. is assumed.
   Cruise control procedure: Constant altitude cruise at a constant Mach

Number of .82 is assumed. This is substantially below the cruise speed capabilities of the J-75 powered DC-8, but is above the long range cruise speed.

3. Schedule patterning
   Probable departure times
4. Airplane characteristics
   Payload limitations
   Empty airplane weight
5. Seasonal factors
   Enroute temperature: Enroute temperature is considered constant for each season. The winter condition assumed is the N.A.C.A. Standard Atmosphere. The summer condition assumed is 20° F warmer than the Standard Atmosphere.

Other factors are considered as statistical variables. These include:

1. Available payload.
2. Required fuel load, which is a function of enroute winds and available payload.
3. Surface climatological factors:
   Temperature at takeoff
   Surface wind at takeoff
4. Deviation of airplane and power plant performance characteristics from their most probable values.

Most of these variables approximate normal probability distributions.

1. They are symmetrically distributed about a mean value.
2. They plot as straight line on normal probability paper.
3. Figure 2 shows the distribution of surface temperature at New York International Airport for the summer season. This distribution shows, for example, that the probability of temperature at 9 A.M. during the summer season at New York International Airport exceeding 80° F is approximately 15%.

Payload is not normally distributed.

1. A positive upper limit is imposed by seating capacity or design weights.
2. The variation of available payload is based upon United Air Lines' experience with DC-7, DC-6, and CV-340.
3. Figure 3 illustrates the distribution of available payloads for two widely different long term average load factors. For example—if the long term load factor is 85%, the probability of obtaining a 100% payload is approximately 21%.

The technique used to combine variables is referred to as the Method of Variance Summation.

1. The method is essentially an application of the central limit theorem.
2. The technique applied is similar to that used in tolerance theory. It avoids combining outside limits.
3. This method was checked by two other techniques.
   (a) A Monte Carlo or Simulation Technique using Random Number Generation. This method assigns random digits to represent each value in a distribution. The number of digits assigned to each value is a function of its likelihood of occurrence. These distributions are then used in connection with a table of random digits to simulate operation from a given airport for any desired period of time. This method was not utilized because of difficulty in determining proper sample size and because of costs involved in programming and operating the method on a large scale computer.

Figure 2

DISTRIBUTION OF SURFACE TEMPERATURE
NEW YORK INTERNATIONAL AIRPORT
SUMMER SEASON - 9 A.M.

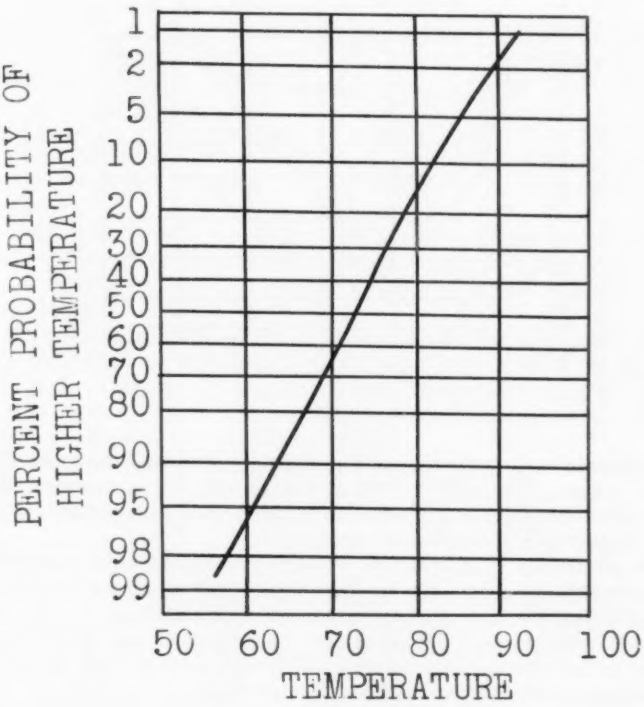
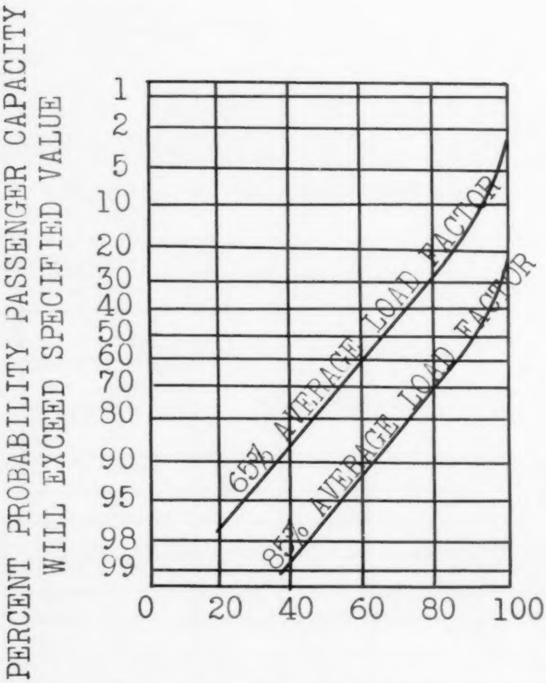


Figure 3



(b) A graphical method of numerically integrating the probability distributions. This method was very accurate, but extremely tedious.
(c) Results obtained using the three methods agreed within the limits of accuracy expected in our analysis.

4. The possibility of correlation between variables was investigated. Correlation factors were not determined, but it was established that correlation factors of likely magnitude would not appreciably change the results, i.e. some correlation may exist between enroute wind and surface temperature, but a correlation factor, even if high, would not appreciably alter the runway length distribution.

Combining the Various Distributions to Obtain Desired Result

1. The mean value and variance of each distribution is determined.
2. All distributions must be converted to common unit of weight or length.
3. The mean value of each variable is combined to determine mean runway length required.
4. The individual variances are added to obtain the variance of the final runway length distribution.

The addition of variances is illustrated by the following formulae:

If Standard Deviation = d
Variance = d^2
Lbs. Fuel Consumed/Lb. Weight = b

$$d^2_{togw} = (1 + b)\, d^2_{payload} + d^2_{\substack{fuel \\ (wind)}} + d^2_{performance\ variation}$$

In above equation all items in terms of weight units.

$$d^2_{fuel\ length} = d^2_{togw} + d^2_{surface\ temp.} + d^2_{surface\ wind}$$

In above equation all items in terms of length units, i.e., $d^2_{surface\ temp.}$ indicates variation in length required due to variation in temperature.

Several "Realism Factors" are adopted in the study to assure valid or conservative results.

1. A 3% loss in takeoff thrust due to installation of a noise suppression device is assumed. It is permissible within terms of some guarantees for the manufacturer to lose this amount in order to attain satisfactory external noise levels.
2. A 5% increase in fuel burnout is assumed. This will include
   (a) Effect of noise suppression device on cruise fuel consumption.
   (b) Increased external drag of noise suppression device and thrust reverser.
   (c) Poorer-than-design performance in engine fuel consumption. Quoted consumption is based on brand new engines. Some deterioration is expected as engines are operated for hundreds of hours between overhauls.
3. Landing Field Lengths are increased 10% above the manufacturer's estimate. This is consistent with the outside limit of the guaranteed landing field tolerance. This is a conservatism for safety reasons. It also permits growth of the airplane in weight or passenger capacity within the landing field lengths specified.
4. Statistical variation from most probable performance is considered.
5. Fuel reserve is adequate for a 300 mile alternate plus one hour holding fuel. (Fifteen minutes in addition to the required CAR 45 minutes.) This amount may be conservative during fair weather conditions, but inadequate for foul weather cases.
6. A semi-high speed cruise procedure is used. Some slight savings in fuel consumption are possible by further reduction of airspeed.

Figure 4 illustrates the effect of realism factors on takeoff field length requirements.

1. The assumption of the 3% thrust loss and the 5% fuel burnout will increase the required field length by from 400 ft. to 1200 ft. depending upon the particular trip length and airport involved.
2. The deviation from most probable performance increases the field length by from 240 ft. to 400 ft. at the 1 chance in 50 level.

There are definite limitations to this study.

1. It must be realized that these distributions represent requirements of United Air Lines for DC-8 operation.
2. Requirements of other operators may dictate longer runway lengths.
3. Many of the inputs are still subject to change.
   Civil Air Regulations
   Final airplane performance

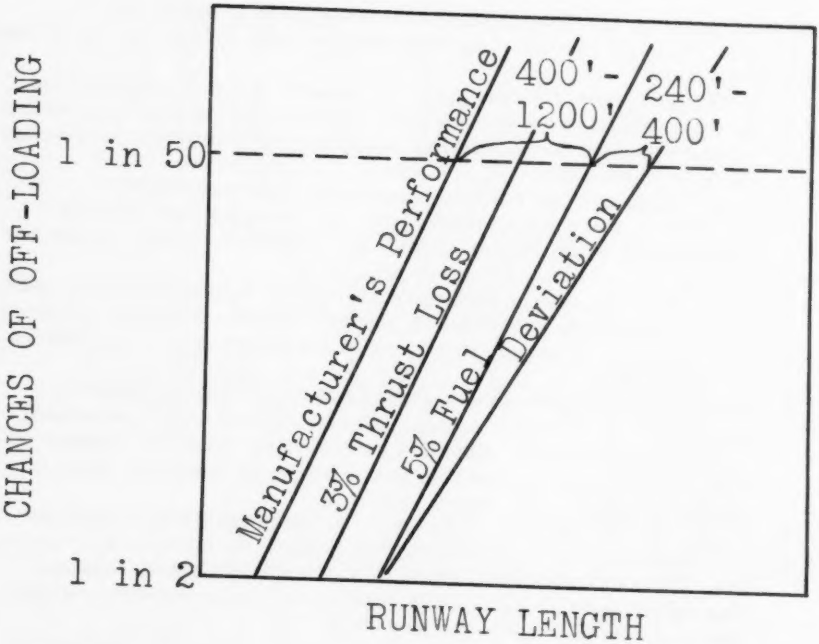

CHANCES OF OFF-LOADING
1 in 50
1 in 2
RUNWAY LENGTH
Manufacturer's Performance
3% Thrust Loss
5% Fuel Deviation
400'-
1200'
240'-
400'

Figure 4

Schedule planning

Traffic control procedures

Results of the analysis of United Air Lines' DC-8 runway requirements at New York International Airport are shown for illustrative purposes in Figure 5. It should be noted that:

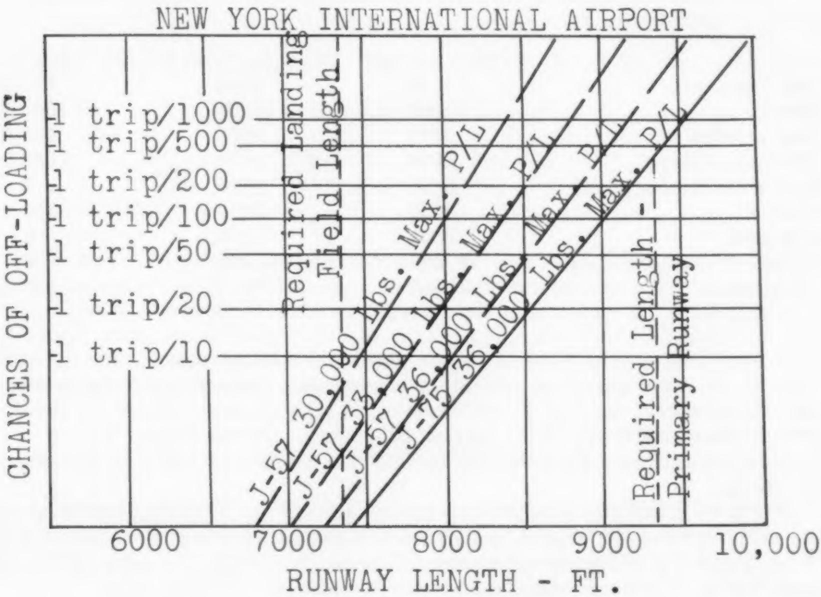


Figure 5

1. The J-75 powered airplane is studied on New York-San Francisco segment during the summer season for departure times of 0900 or 1800.
2. The J-57 powered airplane is studied on the New York-Denver segment during the summer season for departure time of 1300.
3. The market strength is defined as equivalent to a long term average load factor of 85%.
4. Landing Field Length required is 7350 ft. which is substantially below takeoff field length requirements.
5. Payload referred to is the target toward which the airplane will be sold. Chances of off-loading refers to actual off-loading of the payload at the airport available to be carried. It does not refer to off-loading only from the structural or space payload limit of the airplane.

The analysis of the New York International Airport leads to the following conclusions:

1. No extension to the present primary runway 13-31 is required for United Air Lines DC-8 operation. The probability of off-loading for the present length of 9420 ft. is less than 1 chance in 500.
2. It is considered desirable to extend the ILS runway 4-22 to a total length of 8400 ft.

3. It is not considered necessary to extend both runways of a parallel pair to these lengths. Landing requirements are fulfilled with shorter runways. Most takeoffs may also be made from the shorter of a parallel pair. Only the takeoffs for long non-stop trips will require use of the longest runways.

The results of our analysis for the primary runway at several other airports is as follows:

	Present Length	Recommended Length	Extension
San Francisco	8870	9500	630 ft.
Denver	10,000	11,500	1500 ft.
Los Angeles	8560	9000	440 ft.
Chicago, O'Hare	8000	9500	1500 ft.
New York International	9420	9420	0
Seattle	8500	8900	400 ft.
Portland	8800	8800	0
Boston	10,000	10,000	0
Pittsburgh	7500 (+ overrun)	7650	150 ft.

It should be realized that the above results are shown only for the primary runway. In some cases the secondary runway may require more extension than the primary. It is possible, however, to take more advantage for favorable surface headwinds on the secondary runway. The secondary runway lengths required are normally 85% to 90% of the length required on the primary runway.

It will be noted that with two exceptions, Denver and Chicago, extension of the primary runway would be unnecessary if losses were not encountered due to installation of the noise suppression device. The economic and performance penalties for noise suppression are very substantial.

While portions of the analysis have had to be somewhat arbitrary, it is believed that the basic approach is sound. We have tried to be reasonably frugal in our requirements, nevertheless maintaining a realistic outlook. In areas which are not well defined, we have been slightly conservative.

It should be emphasized that it is not possible to specify a single runway length as a standard for operation of a particular aircraft type. Runway requirements at different airports vary widely and must be determined by individual analysis. This analysis requires the close cooperation of the airport operator and the air carriers utilizing the facility.

Paper 1478 December, 1957 AT 2

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

AIRPORT CONFIGURATION[a]

W. E. Cullinan, Jr.[1]
(Proc. Paper 1478)

It seems to be generally agreed that the arrival of the jet transport will mark the beginning of another surge in the vigorous growth of air transportation. It is this growth for which most airports must prepare, rather than the jet itself, since perhaps not more than 50 communities will be involved directly with the first phases of pure jet operation. However, all will be faced with airport expansion problems of some kind.

Expansion Requirements

Thus far, experience has shown that the most common expansion "headaches" of the airport owner come from one or more of 5 principal sources:

a) the need for a longer runway to accommodate new airline equipment or large corporate aircraft; but where topography or approach conditions make the extension of an existing runway impractical; or

b) the need for a better runway to accommodate new approach or landing aids without undue operating restrictions; but where obstructions, gradient, or other undesirable features make the use of an existing runway unfeasible; or

c) the need to enlarge the terminal area, including ramp and gate positions, auto parking areas, passenger facilities, etc., but where the present terminal area is restrained on all sides by highways, hangars, runways, industrial plants, and the like; or

d) the need to find space to accommodate a new industry which desires an airport site in order to simplify air shipment of products or to facilitate the air travel of company executives or technicians by airline or corporate aircraft; or

Note: Discussion open until May 1, 1958. Paper 1478 is part of the copyrighted Journal of the Air Transport Division of the American Society of Civil Engineers, Vol. 83, No. AT 2, December, 1957.

a. Presented at The Jet Age Airport Conference, May 15-17, 1957.

1. Chief, Airports Div., Civ. Aeronautics Administration, Region I, New York, N. Y.

e) the need to increase the airport capacity and runway acceptance rate by development of a parallel runway in order to avoid saturation or obsolescence.

In order to prepare for whichever of these expansion problems may confront a particular community, a thorough study of the airport plan is usually necessary. The solution has often led to a major revision in the airport configuration as an alternative to the construction of a replacement or to the continuation of the airport under severe handicaps - either operational or financial. Fortunately, many such adjustments in the airport configuration have been possible by taking advantage of the "single runway" concept and phasing out one or more of the existing multiple runways. Wherever its application is feasible, considerable property and pavement may be released for other uses.

Runway Pattern and Airport Capacity

This Port Columbus example typifies the problem of many terminal airports where the forecasts indicate a future traffic volume in excess of the ability of the conventional runway system to accommodate it. This situation will become more common in the jet age as the traffic builds up to saturation at more and more airports. Consequently, I would like to devote a few moments to the relationship between airport configuration and airport capacity.

Since instrument weather (IFR) conditions impose the severest limitations on the capability of the runway system to accept and release aircraft, the airport capacity must be established on that basis. It is during these periods that all aircraft must be regimented and held to precise air traffic control procedures. Thus, the instrument runway, equipped with the ILS (Instrument Landing System), becomes practically the sole key to the number of operations which can be handled. Additional, intersecting runways may be helpful or even necessary during good weather or strong cross wind conditions, but are of limited value during instrument weather. On the other hand, an additional runway, properly separated and parallel to the instrument runway, will have a marked effect on the IFR capacity of the airport.

The extent of this effect can, perhaps, be most simply illustrated by a series of sketches showing a few variations in airport configuration with an explanation of the average IFR capacity for each. It should be noted here that these capacities are based on the major airport terminal type of traffic, where the aircraft approach speeds would be nearly equal, where all aircraft would have full radio equipment, where the airport has surveillance and precision approach radar, and where the ratio of arrivals and departures is balanced during the peak period.

a) - Single Runway Pattern

Figure 5 shows the common single runway pattern with an instrument runway and intersecting, cross runway. During IFR weather, take-offs must be interspersed with landings on the same runway, thereby delaying succeeding approaches and slowing down the operational rate. The average IFR capacity of this configuration is 30 operations/ hour.

b) - Parallel Runways - VFR Separation

The pattern in Figure 6 shows the addition of a parallel runway with a 700' lateral separation which is the minimum standard for good weather use. This change improves the good weather rate but has no significant effect on the IFR rate due to the proximity of the runways which will require holding each take-off until each approach had been completed and the aircraft had landed.

c) - Parallel Runways - IFR Separation

Figure 7 illustrates a parallel instrument runway configuration with the minimum separation of 3000' recommended for IFR operation. This pattern has both instrument runways on the same side of the airport terminal area and ramp. In this layout, landings must be conducted on the outboard runway in order to avoid the necessity for departing aircraft to taxi across the path of landing traffic.

After vacating the runway, landing aircraft must be held for clearance across the active take-off runway to the terminal ramp. This will often necessitate the delay of outbound aircraft in order to clear the infield area. Nevertheless, the IFR capacity has been increased by 50% over the single runway pattern to an average rate of 45 operations/hour.

d) - Tandem-Parallel

At some airport locations, terrain or real estate problems may prevent a 3000' lateral separation for parallel runways, but may permit a tandem arrangement as shown in Figure 8, with an alignment separation of approximately 1200'. The tandem feature will compensate for the lack of the full 3000' minimum separation for IFR operation. However, the delays caused by taxiing across an active runway, as in the case of the "side-by-side" parallels of Figure 7, are avoided. Thus, there is a further improvement in the average IFR rate with this configuration to an estimated 55 per hour. It should be noted, however, that if these runways are extended toward each other to create an "overlap" condition, the benefits may be completely lost.

e) - Open-Parallels

The most efficient instrument runway pattern is the "open-parallel" design of Figure 9 where the parallels are separated by the terminal building and ramp area. Arrivals and departures are automatically segregated and any cross traffic is confined to the ramp area. With this arrangement, take-offs and approaches are conducted independently and virtually simultaneously on their respective runways. The average IFR capacity for this configuration is estimated at 65 operations per hour which is just short of the theoretical rate.

This sketch, as well as that of the Dual-Tandem pattern of Figure 8, illustrates the "uni-directional" layout for the parallel instrument runways, where the take-off and approach paths are confined to just one end of each runway. When wind conditions require a 180 degree change in the direction of operations, the use of each runway for landings and take-offs is also reversed. Theoretically, this pattern saves taxiways over those required for bi-directional use as shown for the cross-wind, secondary runway. However, taxiways serving both ends of each runway are desirable at some locations

(Continued on page 14)

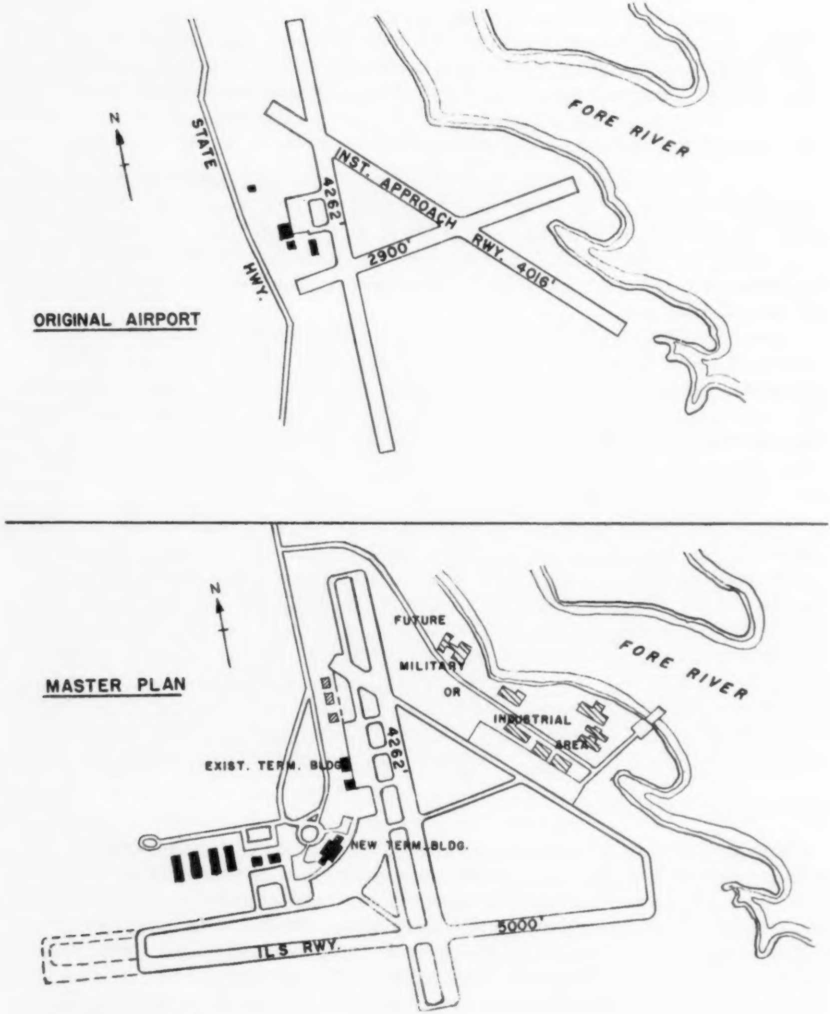

FORE RIVER
N
STATE HWY.
INST. APPROACH RWY. 4016'
4262'
2900'
ORIGINAL AIRPORT
FORE RIVER
N
FUTURE MILITARY OR INDUSTRIAL AREA
MASTER PLAN
4262'
EXIST. TERM. BLDG.
NEW TERM. BLDG.
5000'
ILS RWY.
PORTLAND, ME.

Fig. A.

Examples of Revisions in Configuration

A few "for instances" taken from our experiences in Region I may be helpful in illustrating the point. I will try to cite briefly the original problem in each case and the proposed solution.

Portland, Maine Municipal Airport

Problem

1) - Runways were of insufficient length for air carrier operations and extension was impractical due to approach conditions and topography.

2) - The need for a suitable runway for an ILS installation. Instrument approach runway was too short, had steep longitudinal gradient, and was partially obstructed.

3) - Building area for hangars and terminal expansion was too small and was confined by runway clearances and a highway.

Solution

1) - The state highway was rerouted, permitting construction of a new E/W instrument runway with clear approaches and flat grades and with expansion possibilities to 7000'.

2) - Two runways (NW/SE and old E/W) were eliminated except for portions which were incorporated into the new Master Plan as taxiways. The N/S runway was retained as a secondary runway.

3) - Larger areas were made available by the adjustments for hangar space, industrial or military use, and future terminal development.

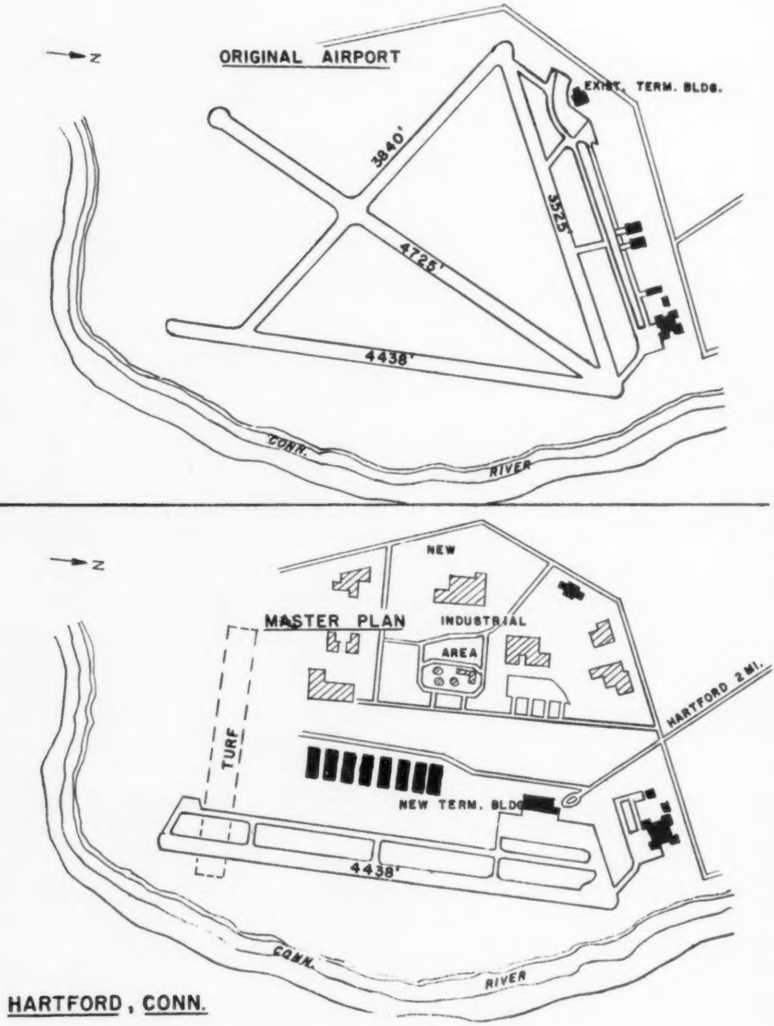

ORIGINAL AIRPORT
EXIST. TERM. BLDG.
3840'
3525'
4725'
4438'
CONN. RIVER
NEW
MASTER PLAN
INDUSTRIAL
AREA
HARTFORD 2 MI.
TURF
NEW TERM. BLDG.
4438'
CONN. RIVER
HARTFORD, CONN.

Fig. B.

Brainard Field, Hartford, Connecticut

Problem

1) - Airlines transferred all schedules to larger airport at Bradley Field in order to consolidate Hartford and Springfield, Massachusetts traffic.

2) - The scarcity of property within City limits for industrial growth and the threat of losing an existing industry.

3) - Proposal of the City to sell entire airport property for industrial development and relocate 75 based aircraft to remote locations. (Airport is 5 minutes from business district and State Capitol).

Solution

1) - A study resulted in the redesign of the airport which provided for retention of the principal runway for general aviation. This released nearly one-half the airport property for industrial use through the elimination of two existing runways.

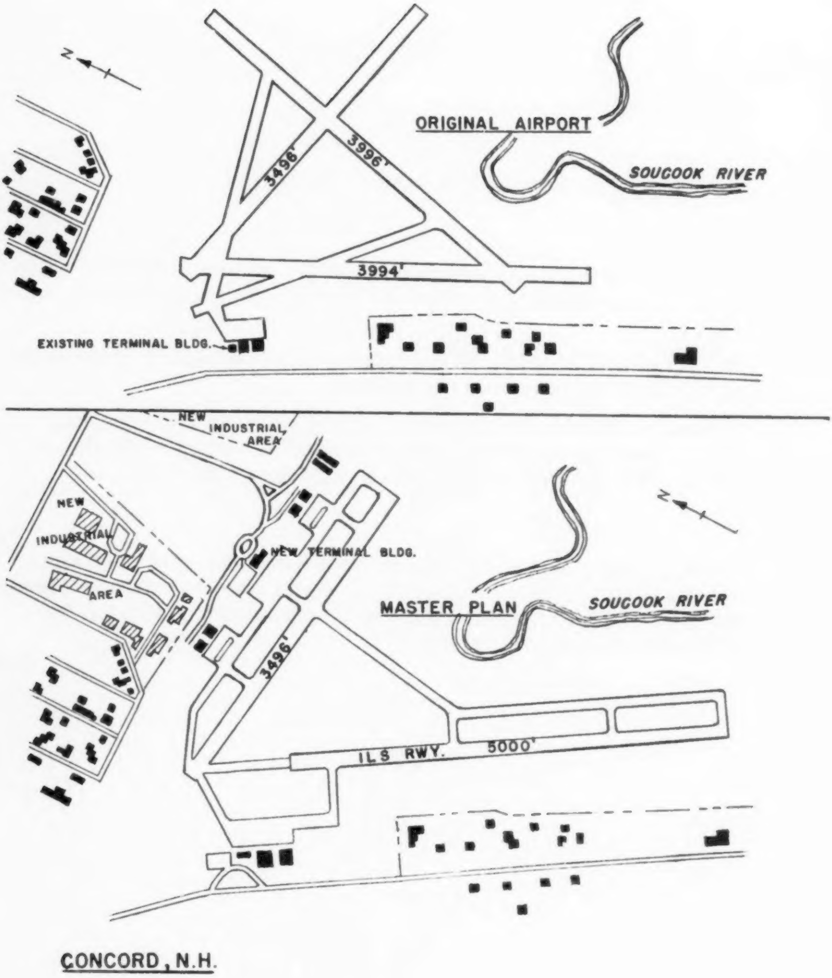

ORIGINAL AIRPORT
SOUCOOK RIVER
3496'
3996'
3994'
EXISTING TERMINAL BLDG.
NEW INDUSTRIAL AREA
NEW INDUSTRIAL AREA
NEW TERMINAL BLDG.
MASTER PLAN
SOUCOOK RIVER
3496'
ILS RWY. 5000'
CONCORD, N.H.

Fig. C.

Concord, New Hampshire Municipal Airport

Problem

1) - The north approach of the instrument runway was obstructed by a housing development.

2) - The space available for expansion of the terminal and hangar area was limited by runway clearances and adjacent private property.

3) - Some pressure was being exerted to dispose of all airport property except the runways and a small administration building for industrial development. (Negotiations for approximately 40 acres presented the prospect of the first new industry in Concord in 30 years. The company proposed construction of a hangar adjoining the landing area, as well as its new plant).

Solution

1) - The redesign provides for relocation of threshold on north end of instrument runway in order to clear the approach. South end to be extended to compensate and to increase the length.

2) - The elimination of 3 surplus runways with the use of a portion of the NE/SW for taxiway purpose in the ultimate plan.

3) - Plans made for new terminal and hangar area at the location made available by abandonment of NE/SW runway.

4) - The release of 2 large areas for sale as industrial property.

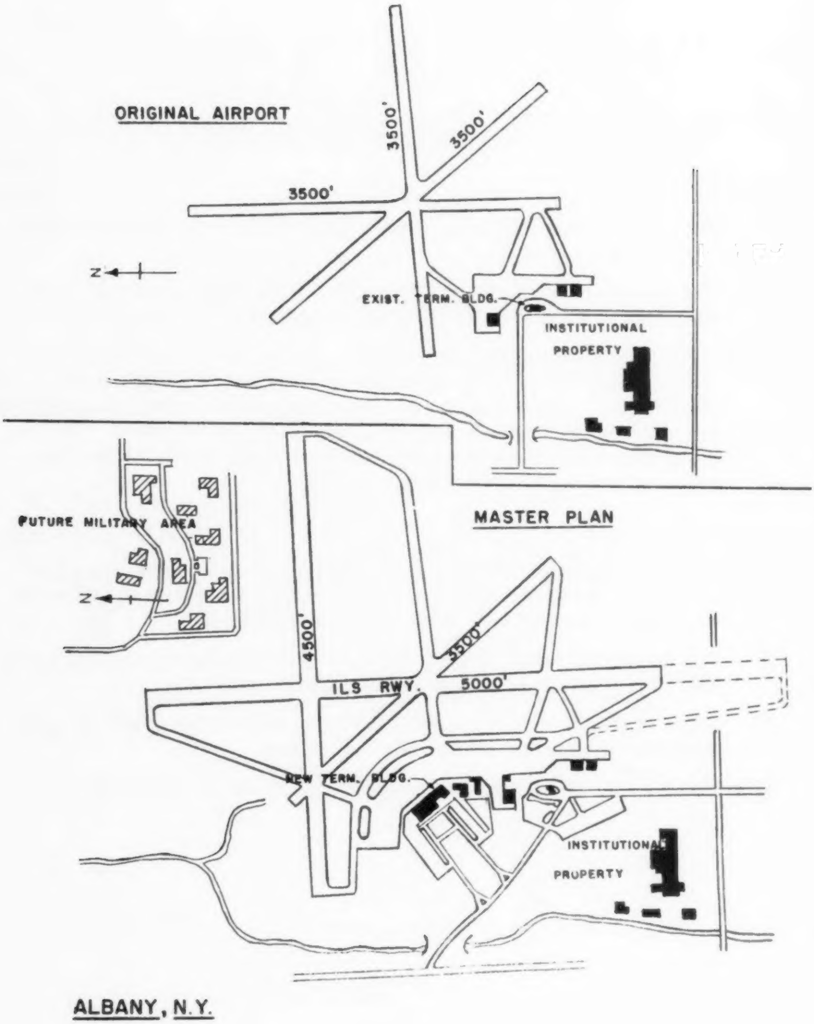

ORIGINAL AIRPORT
3500'
3500'
3500'
Z
EXIST. TERM. BLDG.
INSTITUTIONAL
PROPERTY
MASTER PLAN
FUTURE MILITARY AREA
Z
4500'
3500'
ILS RWY. 5000'
NEW TERM. BLDG.
INSTITUTIONAL
PROPERTY
ALBANY, N.Y.

Fig. D.

Albany, New York Municipal Airport

Problem

1) - The instrument runway (N/S) was too short and equipped with insufficient taxiways for efficient ground movement.

2) - The secondary runway (E/W) was too short and obstructed.

3) - The terminal building area and services were grossly inadequate and any expansion was restrained by runways and institutional property.

4) - The terminal building activities were divided into two separate structures, both of which were too small.

Solution

The Master Plan revision provided for several major changes, many of which have been accomplished.

1) - Extension of the instrument (N/S) runway.

2) - Abandonment of the obstructed E/W runway except for use as a taxiway.

3) - Construction of a new secondary runway (E/W).

4) - Expansion of the terminal area on to the land released by the abandonment of the old E/W runway and contiguous to existing hangar area.

5) - Development of a new terminal building for the consolidation of airline activity and for the provision of normal customer services.

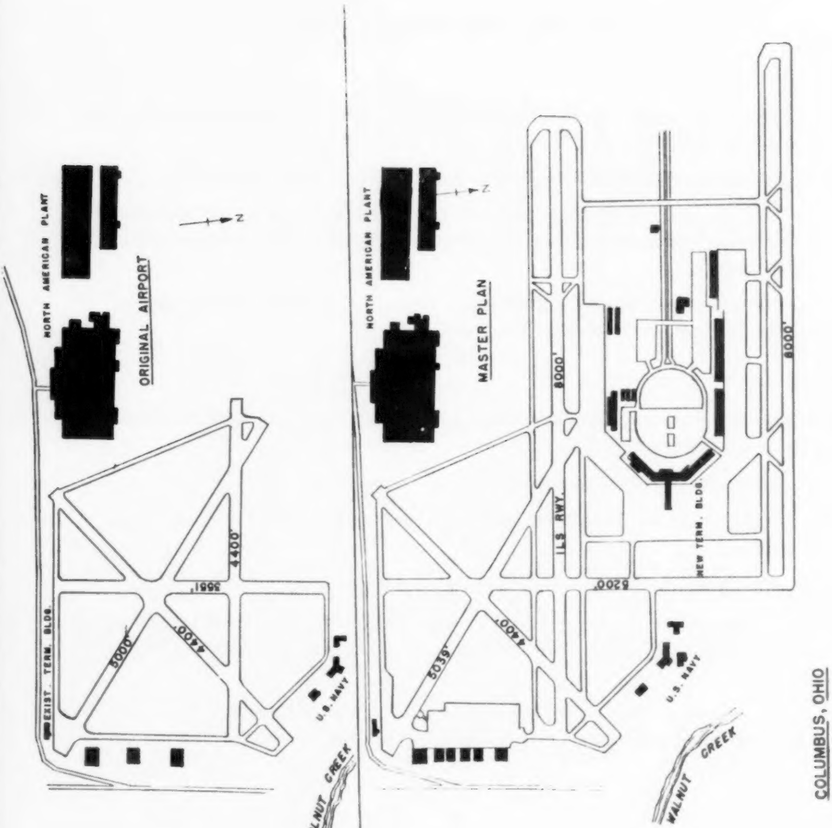

ORIGINAL AIRPORT
NORTH AMERICAN PLANT
EXIST. TERM. BLDG.
5000'
4400'
3561'
4400'
U.S. NAVY
WALNUT CREEK
MASTER PLAN
NORTH AMERICAN PLANT
8000'
8000'
ILS RWY.
NEW TERM. BLDG.
5200'
4400'
5039'
U.S. NAVY
WALNUT CREEK
COLUMBUS, OHIO

Fig. E.

Port Columbus, Ohio Airport

Problem

1) - The terminal building and loading ramp were grossly inadequate and incapable of improvement.

2) - The need for a longer runway and greater airport capacity was becoming critical due to the increase in military, manufacturing, and civil flight operations.

Solution

1) - Extension of the instrument runway.

2) - Abandonment of the NW/SE runway and the development of a new terminal area in its approach.

3) - Plan for construction of a parallel instrument runway north of new terminal area with sufficient lateral separation to insure maximum airport capacity.

where there is an unbalance between take-offs and landings during a peak period and where the use of both runways for departures is needed to expedite traffic. For instance, between 7 A.M. and 9 A.M. at New York, there is a heavy volume of outbound flights compared to arrivals.

Secondary Runways

A secondary runway has been included in all of these illustrations to cover situations where strong cross-wind components (15 mph or more) are periodically experienced on the principal or instrument runway. These conditions usually occur during good weather, at which times the VFR capacity of the single runway is generally adequate to accommodate the traffic. Where it is not, the instrument runway can be used as a supplement for take-offs, if cross-wind conditions are not too severe. For this reason, it is desirable to avoid intersections in the design of the runway layout in order to permit maximum simultaneous use of diverging runways. In either event, a parallel secondary runway is usually not required. The taxiway system should be designed for bi-directional use and provided with high-speed exits.

CONCLUSION

Limitations of terrain and real estate may occasionally preclude the design of an airport configuration which will provide sufficient capacity to accommodate the traffic forecasts. In such cases, plans must be made for a supplementary airport in the area. For either situation, improvement of the old or design of the new, it is hoped that this discussion may provide a little helpful guidance in preparing airport plans for the jet age of aviation.

Supplement to "Airport Configuration"

In presenting the paper on "Airport Configuration" at the ASCE Jet Age Conference, several sketches pertaining to taxiways were omitted. It was felt that this material might be of interest as a supplement.

Figure 1 shows the Twin-Stack Feed with radar control which makes possible theoretical clearances to the runway at a 1-1/2 minute interval or 40 per hour rate, thus pointing up the need for speed in vacating the runway for the following aircraft.

Figure 2 provides the details of exit taxiways designed to accommodate aircraft turning off the runway at a 40 mph speed.

Figure 3 illustrates the recommended spacing of high-speed exits for turn-offs at 40 mph at large airline terminals. At smaller terminals, the more distant exits may be eliminated, consistent with the runway length.

Figure 4 illustrates a holding apron design which will facilitate "rolling take-offs," thus speeding up departures.

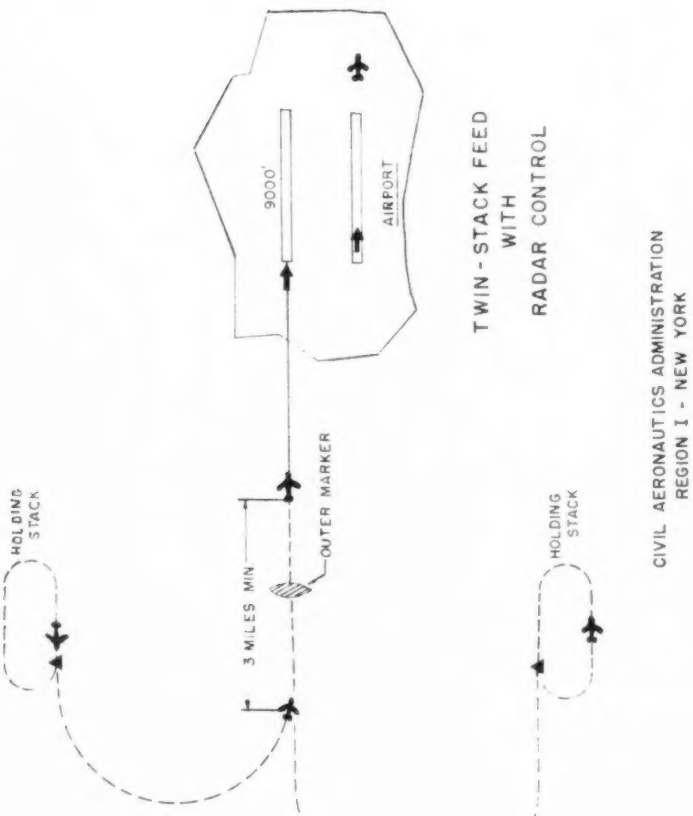
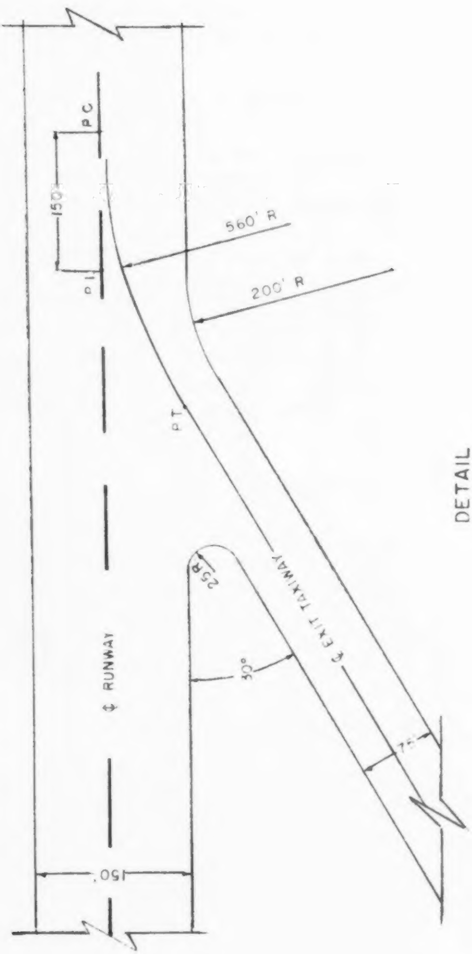

HOLDING STACK
HOLDING STACK
3 MILES MIN
OUTER MARKER
9000'
AIRPORT
TWIN - STACK FEED
WITH
RADAR CONTROL
CIVIL AERONAUTICS ADMINISTRATION
REGION I - NEW YORK
AIRPORTS DIVISION

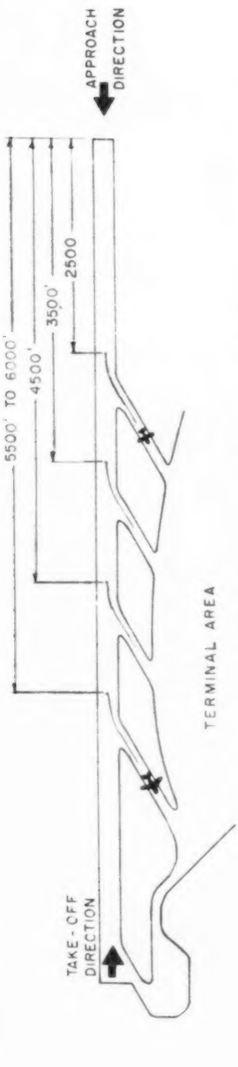
FIG. 1



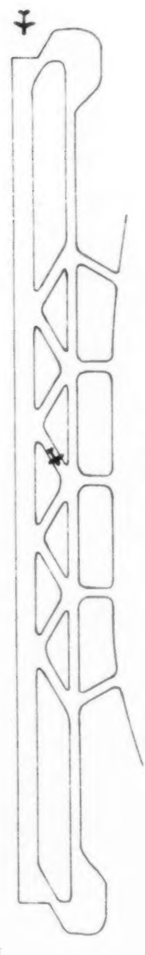
DETAIL
OF
HIGH SPEED EXIT TAXIWAY

CIVIL AERONAUTICS ADMINISTRATION
REGION I - NEW YORK
AIRPORTS DIVISION

FIG. 2



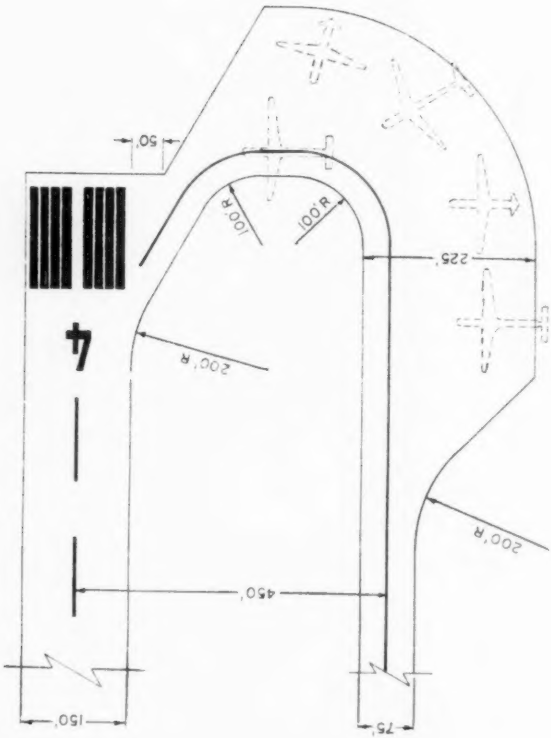
EXIT TAXIWAYS FOR UNI-DIRECTIONAL RUNWAY



EXIT TAXIWAYS FOR BI-DIRECTIONAL RUNWAY

CIVIL AERONAUTICS ADMINISTRATION
REGION I - NEW YORK
AIRPORTS DIVISION

FIG. 3



DETAILS OF HOLDING APRON
&
ENTRANCE TAXIWAY

CIVIL AERONAUTICS ADMINISTRATION
REGION I - NEW YORK
AIRPORTS DIVISION

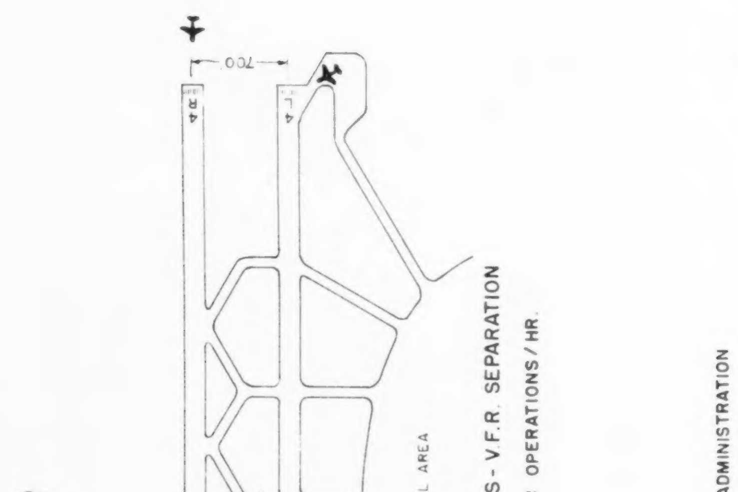
FIG. 4

SINGLE RUNWAY PATTERN

IFR CAPACITY 30 OPERATIONS/ HR.

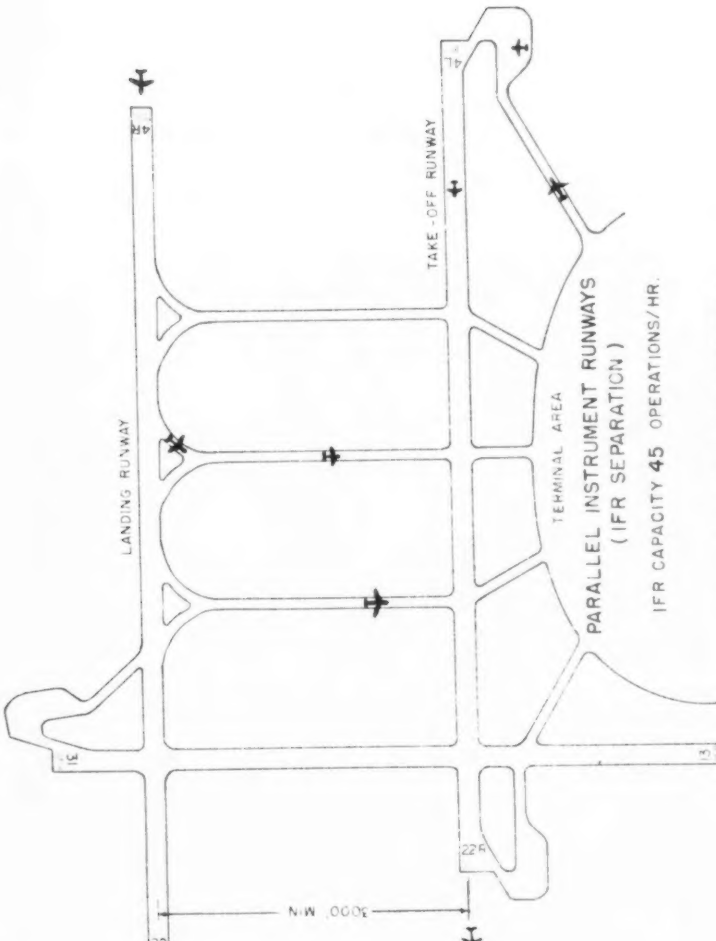
CIVIL AERONAUTICS ADMINISTRATION
REGION I - NEW YORK
AIRPORTS DIVISION

FIG 5



4R
4L
700
22L
22R
35
17
TERMINAL AREA
PARALLEL RUNWAYS - V.F.R. SEPARATION
IFR CAPACITY 30 OPERATIONS / HR.
CIVIL AERONAUTICS ADMINISTRATION
REGION I - NEW YORK
AIRPORTS DIVISION

FIG. 6



PARALLEL INSTRUMENT RUNWAYS
(IFR SEPARATION)

IFR CAPACITY 45 OPERATIONS/HR.

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AIRPORTS DIVISION

FIG. 7

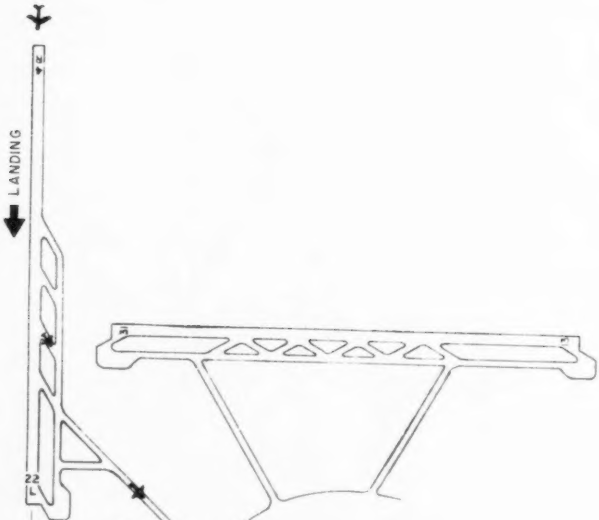

FIG. 8

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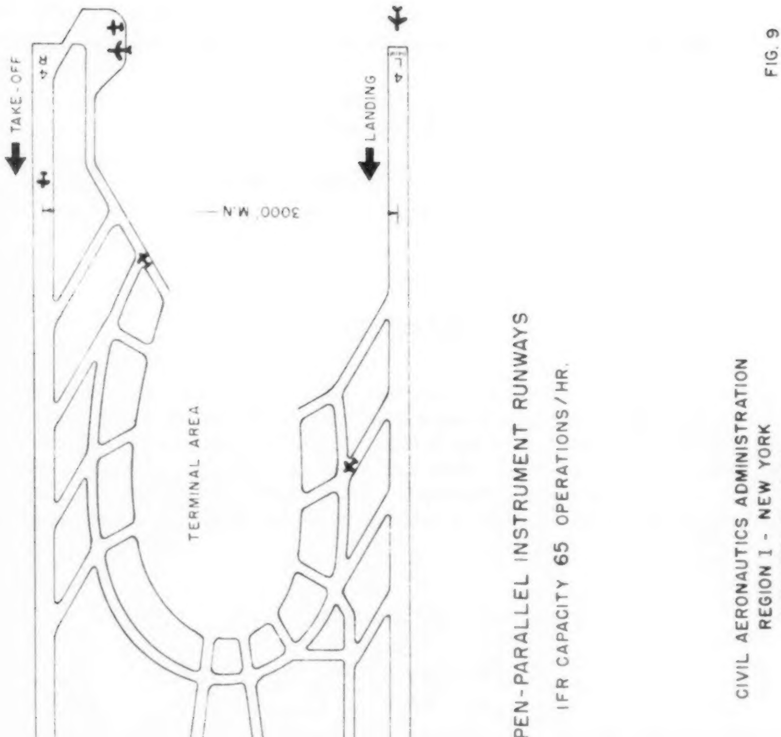

OPEN-PARALLEL INSTRUMENT RUNWAYS

IFR CAPACITY 65 OPERATIONS/HR.

CIVIL AERONAUTICS ADMINISTRATION
REGION I - NEW YORK
AIRPORTS DIVISION

FIG. 9

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

EFFECTS OF JET BLAST AND FUEL SPILLAGE ON BITUMINOUS PAVEMENTS[a]

W. J. Turnbull* and Charles R. Foster,** M. ASCE
(Proc. Paper 1479)

ABSTRACT

Studies conducted by the Corps of Engineers for the U. S. Air Force in connection with the effects of jet blast and fuel spillage on bituminous military airfield pavements show that the heat and blast effects become critical on tar concrete, asphaltic concrete, and rubberized-tar concrete pavements at 250, 300, and 315°F, respectively. Repeated fuel spillage in one spot is detrimental to asphaltic concrete, but has no adverse effect on tar or rubberized-tar concrete.

INTRODUCTION

The hot gases that impinge on the pavement, and the fuel that is spilled on the pavement during ground operations of jet aircraft have created problems for the pavement designer that were not encountered with propeller-driven aircraft. The Corps of Engineers has studied these problems for several years as part of the over-all development of design criteria for airfield pavements being accomplished for the U. S. Air Force. Some of the information

Note: Discussion open until May 1, 1958. Paper 1479 is part of the copyrighted Journal of the Air Transport Division of the American Society of Civil Engineers, Vol. 83, No. AT 2, December, 1957.

a. Paper prepared for presentation at Jet Age Airport Conference, New York, N. Y., May, 1957.

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**Eng., Chief, Flexible Pavement Branch, Soils Div., Waterways Experiment Station, CE, U. S. Dept. of the Army, Vicksburg, Miss.

derived from these investigations has been presented previously[1, 2, 3,]; this paper summarizes the results.

The studies have considered (a) the characteristics of the blast of jet aircraft and the effect of jet blast on bituminous pavements, (b) the characteristics of fuel spillage of jet aircraft and the effect of spillage on asphaltic pavements, and (c) fuel-resistant bituminous pavements.

The studies discussed herein have been conducted under the supervision of the Office, Chief of Engineers. Messrs. Gayle McFadden (now retired) and W. C. Ricketts of the Airfields Branch of the Office, Chief of Engineers, monitored the studies. Guidance was furnished by Professor W. J. Emmons and Messrs. J. L. Land and F. S. Gilmore in the capacity of consultants. Mr. H. J. Skidmore, deceased, was also a consultant. The laboratory and field work was accomplished by the Corps of Engineers Flexible Pavement Laboratory, Waterways Experiment Station, Vicksburg, Mississippi, and Rigid Pavement Laboratory, Ohio River Division, Cincinnati, Ohio. The Air Force provided and operated all aircraft used in these studies and assisted in the tests and observations at the airfields. Acknowledgment is also given to the U. S. Navy and the British Air Ministry for test results and data received through official channels.

Jet Blast, Air Force Aircraft

In the late summer of 1951 the Corps of Engineers and Headquarters U. S. Air Force collaborated on a plan of observations and tests to determine the normal operating behavior of jets from the standpoint of heat and blast by means of time-movement studies and detailed observations at a number of Air Force bases. The observers clocked the travel of aircraft through the entire range of movement from starting on the apron to take-off. The observations indicated that the jet blast of aircraft operated without afterburners had a serious effect only during the pretake-off check at the end of the runway and during maintenance run-ups on the aprons. Other conditions of operation were much less severe than these two.

From the results of the time-movement studies, typical run-ups were established for pretake-off checks and for maintenance testing which have been used in subsequent tests to determine the temperatures that can be expected in pavements when subjected to normal operation of jet aircraft. Normal time periods of 1-1/2 and 2-1/2 minutes were established for pretake-off checks of fighters and bombers, respectively, and 14 minutes for maintenance run-ups for both. The investigations showed that during pretake-off checks, the engines were normally operated at 40% power or so-called idle power for about 70% of the time period and at 70% power for the remainder, with a short burst to 100% power at the end of the period to check emergency fuel, followed by 100% power at take-off. The plane started moving as soon as 100% power was applied. Maintenance run-ups followed no particular pattern, but it was observed that they were generally made at idle power with occasional build-up to 100% power. For test purposes, a simulated maintenance run-up was established as successive cycles of 5-1/2 minutes at idle power followed by 1-1/2 minutes at 100% power. Two cycles were considered as typical of prototype operations.

The use of afterburners while the planes were standing still was not observed; however, test procedures for planes with afterburners were established

in 1954 after discussion with personnel of the Flight Test Center at Edwards AFB, Calif. The simulated pretake-off check at the runway end consisted of one minute at idle power, 15 seconds at military power which is with the jet engine running at 100% full power without the afterburner, and one to two seconds at full power which is with the jet engine running at 100% full power with afterburner. The simulated maintenance run-up procedure was the same as described previously but with the afterburner operated during the 100% power periods.

Tests were made to measure the temperatures induced in bituminous pavements at Eglin Field, Florida, in 1952, at Presque Isle Air Force Base, Maine, in 1953, at the Waterways Experiment Station in 1954, and at Davis-Monthan Air Force Base, Arizona, in 1954. Planes used in the tests were the F-80, F-84, F-86, F-89, F-94, T-33, B-45, B-47, and a Century series fighter. Tests with afterburner operating were made for only the last-named aircraft. In these tests, thermocouples were embedded in the surface and at various depths in the pavement and the temperatures induced during operations of the typical power cycles previously described were recorded. In the tests at the Waterways Experiment Station, which were all made with an F-80 plane, the aircraft was positioned with the tailpipe at various heights above the pavement and at various angles with respect to the pavement.

In addition to temperature measurements, the pavement was observed to determine if erosion occurred, and if so, at what temperature. In many of the tests at the Waterways Experiment Station the power cycle was extended and the angle increased to deliberately erode the pavements so that temperatures at which erosion started could be determined. Photograph 1 shows a typical blast test on a flexible pavement.

The results of the tests in which aircraft were operated without afterburners and in accordance with the typical power schedules indicate the following:

a. Maintenance run-ups, as might be expected since they involved the maximum exposure, developed the highest temperatures in the pavements.

b. Temperatures developed in pretake-off run-ups were comparatively low.

c. The maximum temperature developed in the pavement by a fighter-type plane was 295 F, which occurred with the Century series aircraft; the maximum for the other fighter aircraft was 248 F.

d. The maximum temperature produced by the B-45 bomber-type plane was 385 F and by the B-47 aircraft was 302 F, which occurred for the outboard engine.

e. When the temperature of bituminous pavements exceeds a certain critical figure, the bituminous cement melts and the blast erodes the pavement. At lower temperatures there is no damage from jet blast. Critical temperatures for bituminous pavements are:

Asphaltic concrete	Approximately 300 F
Tar concrete	Approximately 250 F
Rubberized-tar concrete	Approximately 315 F

f. The heat induced in the pavement by jet aircraft is dependent to a very large degree on the angle of the tailpipe and its height above the surface, as shown by fig. 1. The type of engine and the size of the tailpipe are also factors but of less importance than the height and angle.

Temperatures induced in the pavement when the afterburners are operated with the aircraft standing are much higher than those listed above. Fig. 2

shows typical temperature-versus-time curves for operations with afterburner. In the test on asphalt pavement to simulate pretake-off check, where the afterburner was cut in for only one or two seconds, the pavement temperature rose immediately to about 360 F. The duration of this high temperature was so short that no erosion of the pavement occurred, even though this pavement eroded in other tests at approximately 290 F under sustained high temperature. In the simulated maintenance run-ups, temperatures of 600 to 700 F were recorded. These high temperatures produced rapid erosion of the bituminous pavement and the curves shown on fig. 2 for the maintenance run-ups with afterburners were measured in portland-cement concrete.

The Corps of Engineers Flexible Pavement Laboratory makes frequent condition surveys and inspections of pavement at operating air bases and has noted the effect of jet blast under actual operating conditions. The findings are summarized as follows:

Seal Coats and Surface Treatments.—Seal coats and surface treatments are seriously affected by jet blast. The seal coats are often made with bitumens that melt at lower temperatures than the cements used in bituminous concretes and the blast erodes seal coats quicker than bituminous concretes. Also, thin layers such as surface treatments can be lifted up bodily and blown aside by the blast.

Bituminous Concretes.—Field inspections have indicated erosion of bituminous-concrete pavements at runway ends and on some aprons. The erosion occurs in a typical pattern approximately 4 to 6 ft wide and about twice as long, roughly elliptical in shape about as shown in photograph 1. Eroded areas are generally shallow and unsightly but erosion is not significant enough to require individual maintenance. The majority of the eroded areas can be traced to the outboard engine of the B-47 bomber and to the F-89 fighter.

Jet-fuel Spillage, Air Force Aircraft

In April 1953 a survey of jet operations on parking aprons was made at three U. S. Air Force bases in Florida prior to performance of a series of spillage tests on several flexible pavements at the Waterways Experiment Station. The primary purpose of the survey was to determine the normal amounts and frequency of fuel spillage on parking aprons and a realistic ratio of traffic to spillage on a given area. One of the bases surveyed was used entirely by bombers, another by fighters and bombers, and the third was a multipurpose base. In addition, the effects of spillage have been observed at many air bases. The main findings are as follows:

a. Where a group of planes is assigned to a base, each plane generally has a designated parking area and is parked in almost exactly the same spot after each flight.

b. Jet fuel is spilled on the pavement in almost exactly the same spot each time an engine is cut off, either following a flight or following an engine check. Fuel falls from a height of about 6 to 7 ft from bombers and about 2-1/2 ft from fighter and trainer planes.

c. The quantity of fuel spilled is from 1-1/2 to 2 pt for each engine cutoff. This amount of spillage occurs in about two minutes.

d. Jet plane operations range from less than one flight a day to as many as four flights a day depending on the type of aircraft and the training programs. Flights by small planes are as frequent as every two hours.

e. One wheel of the aircraft (or one pair of wheels for dual-wheeled craft) usually runs through the edge of a spillage area when the plane is taxied from the parking area.

f. In addition to the repeated spillage, spillage occurs during the refueling operations. Repeated spillage was observed on a refueling apron where planes taxied alongside the fuel hydrants and cut off their engines.

g. Repeated spillage in the same spot softens and leaches out asphaltic cement leaving the aggregate exposed in a loose state. Occasional spillage evaporates and causes no significant damage to asphaltic pavements.

h. Damage from fuel spillage has been noted only on parking aprons and refueling aprons. Damage has ranged from negligible to severe. The area involved on parking aprons is small, being no more than 30 to 60 sq ft for each parking stall.

Controlled tests were made at the Waterways Experiment Station on several asphaltic-concrete pavements to study the effect of spillage. As a result a standardized spillage procedure was adopted to simulate the most severe normal condition that must be considered in pavement design. The standardized procedure consisted of spilling JP-4 fuel at the rate of 1 qt four times per day. The fuel was spilled from a height of 30 in. above the pavement in a manner simulating spillage resulting from engine cutoff of the single-engine plane. Photograph 2 shows the setup for spillage on the Waterways Experiment Station test section. The 1-gal can used had a small hole punched in it with the orifice such that 1 qt of fuel was spilled in about two minutes. In not less than two hours after each spillage cycle, one pass of a 10,000-lb single-wheel load (200-psi tires) was made through the spillage area to simulate traffic that normally occurs at this location as the plane is moved out for the next mission.

Photograph 3 shows the effect of three days of spillage, four cycles a day, on warm, dry pavement. Fuel attacked the asphalt quickly, covering a small area as it softened and penetrated the surface. After three days of spillage, leaching at the surface was rather severe. Spillage was continued for a total of 52 cycles, or 13 days. The affected area by this time was about 4 ft long and 2 ft wide. The loose stone could be removed with a wire broom. At the point of spillage leaching had occurred to a depth of approximately 1 in.

Tests were made at WES to determine the effect of (a) number of cycles of spillage per day, (b) pavement temperature, (c) water on the pavement, and (d) new versus old pavement. From these tests it was concluded that the number of cycles a day was an important variable but that the other items were minor variables. As the cycles of spillage were increased, the rate of leaching increased; however, any rate such that spillage is repeated in the same spot so fast that fuel does not evaporate between spillages will cause leaching of the asphalt cement to an extent that is not acceptable.

In addition to the spillage tests made directly on asphalt pavement, spillage tests have been made at WES on several compounds recommended as "jet-resistant seals" for asphalt pavement.[4] Most of the materials tested have been special paints or compounds applied as relatively thin films. To date no protective treatments have been found that are satisfactory. Practically all of the materials were, in themselves, resistant to the effects of jet fuel; however, the thin film did not provide complete protection to the asphalt pavement. In some cases the seal was removed under traffic; in other cases the film would shrink and crack with age. Also, many of the seal coats eroded under blast at relatively low temperatures.

Tar is relatively insoluble in jet fuel; therefore a tar-concrete pavement is resistant to jet-fuel spillage. But tar concrete erodes under blast at relatively low temperatures. The addition of rubber to the tar improves the resistance to erosion. The Flexible Pavement Laboratory has studied rubberized-tar concretes as a means of producing jet-fuel-resistant bituminous pavements.(4) These studies have formed the basis for interim specifications for rubberized-tar cement and modifications to the Corps of Engineers mix design procedures so that rubberized-tar-concrete mixes can be designed. In accelerated traffic testing at the WES, rubberized-tar concrete showed satisfactory performance under traffic of a load cart equipped with 200-psi tires. Under jet blast, the erosion temperature was slightly above 300 F; therefore, the erosion resistance equals that of asphaltic concrete or is slightly better. Spillage produces no softening or leaching of the rubberized tar but may cause the rubberized-tar concrete to age faster than normal. The effect of aging and weathering cannot be determined in accelerated traffic tests, consequently the long-term durability of rubberized-tar concretes is not known, and can only be learned with time. Rubberized-tar-concrete aprons have been built at several Air Force bases. Excessive shrinkage cracking occurred in two cases which were constructed early in the program. Those constructed later are showing reasonably satisfactory performance and are being observed for the effects of weathering as well as the effects of traffic, spillage, and blast.

Summation, Air Force Aircraft

The results of the tests and observations made to date may be summarized as follows:

a. Jet blast is critical for hot-mix asphaltic-concrete pavements only at the ends of runways and on aprons where maintenance run-ups are made. The effect of jet blast in other areas (taxiways and runways except the ends) is not detrimental to hot-mix asphaltic-concrete pavement.

b. The critical erosion temperatures of bituminous-concrete pavements subjected to heat and blast are in the order of 250 F for tar, 300 F for asphaltic-concrete pavements, and 315 F for rubberized-tar-concrete pavements. Pavement temperatures developed by most of the U. S. Air Force planes operating today are less than 300 F except when afterburners are used.

c. Operation of afterburners with the plane standing still produces high temperatures in the pavement and will cause erosion of bituminous pavements if continued for any appreciable period of time.

d. Occasional spillage of jet fuel on dense, hot-mix asphaltic-concrete pavement is not detrimental. Repeated spillage, such as that occurring on parking and refueling aprons, is detrimental because the fuel leaches the asphalt cement from the aggregate. The areas affected are relatively small. A pavement resistant to jet fuel is necessary in these areas.

e. No completely satisfactory jet-fuel-resistant seal coats for asphalt pavement have yet been tested.

f. Rubberized-tar concrete pavements are jet-fuel resistant and have given reasonably satisfactory performance so far. The effects of aging are not known.

Commercial Jet Aircraft

The studies described previously have pertained entirely to Air Force fields and aircraft. One of the problems facing airfield designers in the future is the advent of jet aircraft for commercial use. Table 1 lists the three jet and two turbojet aircraft now operating or which will be operating in the future. The table shows the engine designations and available information on the height and angle of the engines with respect to the pavement surface and estimated temperatures that will be induced in the pavement. The figures indicated are company estimates and were provided by the companies; those shown as Flexible Pavement Laboratory were obtained by plotting the respective angle and height on fig. 1 and reading the indicated pavement temperatures. Since the engines that will be used on the commercial jets are not the same as those used in the tests with military aircraft, the Flexible Pavement Laboratory estimates cannot be considered as accurate but only as a trend. It will be noted that the indicated temperatures are relatively low and are well below the erosion temperatures of bituminous pavements.

Table 1

Aircraft	Engine	Ht Above Pavement In.	Angle Deg	Max Pavement Temperature, F Company Est	FPL Est	Fuel Spillage on Cutoff
Viscount	Turbo prop Rolls Royce Bart 506 and 510	--	--	Ambient	---	1/2 pt—no scavenger
Douglas DC-8	Jet P&WA J57 and J75	70	2.0	175	145	3/4 gal—has scavenger
Boeing 707	Jet P&W JT3C-4 and JT4A-3	60	2.0	200	175	3/4 gal—has scavenger
Lockheed Electra	Turbo prop Allison 501-D13	96	1.0	50 (Above Ambient)	---	1 pt—no scavenger
Convair	Jet GE J79	--	--	---	---	---

Heights and temperatures are for inboard engines, outboard engines are less critical.
Source: Viscount, Capital Airlines, DC-8-Douglas, 707 Boeing, Electra Lockheed, Convair.

The data in the last column of table 1 indicate the spillage that can be expected at the parking stall. All the aircraft will release fuel when the engines are cut off. Two of the aircraft have scavengers to catch the released fuel, but the other two do not. Unless all aircraft are equipped with scavengers, consideration must be given to either catching the spilled fuel manually in the parking stall or providing spillage-resistant pavements for parking areas. Fuel-resistant pavements should also be considered at other locations, such as refueling points where fuel may be spilled frequently.

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2. McFadden, Gayle, The Effect of Jet Aircraft on Airport Pavements. ASCE Convention Preprint Paper No. 92, March 1953.

3. Foster, Charles R., and Meredith, E. C., "Effect of heat and blast and fuel spillage by jet planes on asphalt pavement." Proceedings, Association of Asphalt Paving Technologists, 1955.

4. Waterways Experiment Station, CE, U. S. Army, Summary of Investigations of Effects of Jet Blast, Fuel Spillage, and Traffic on Experimental Tar-rubber-concrete Pavements. Technical Memorandum No. 3-420, November 1955.

Photograph 1. Asphalt pavement eroded by blast of F-80 plane.

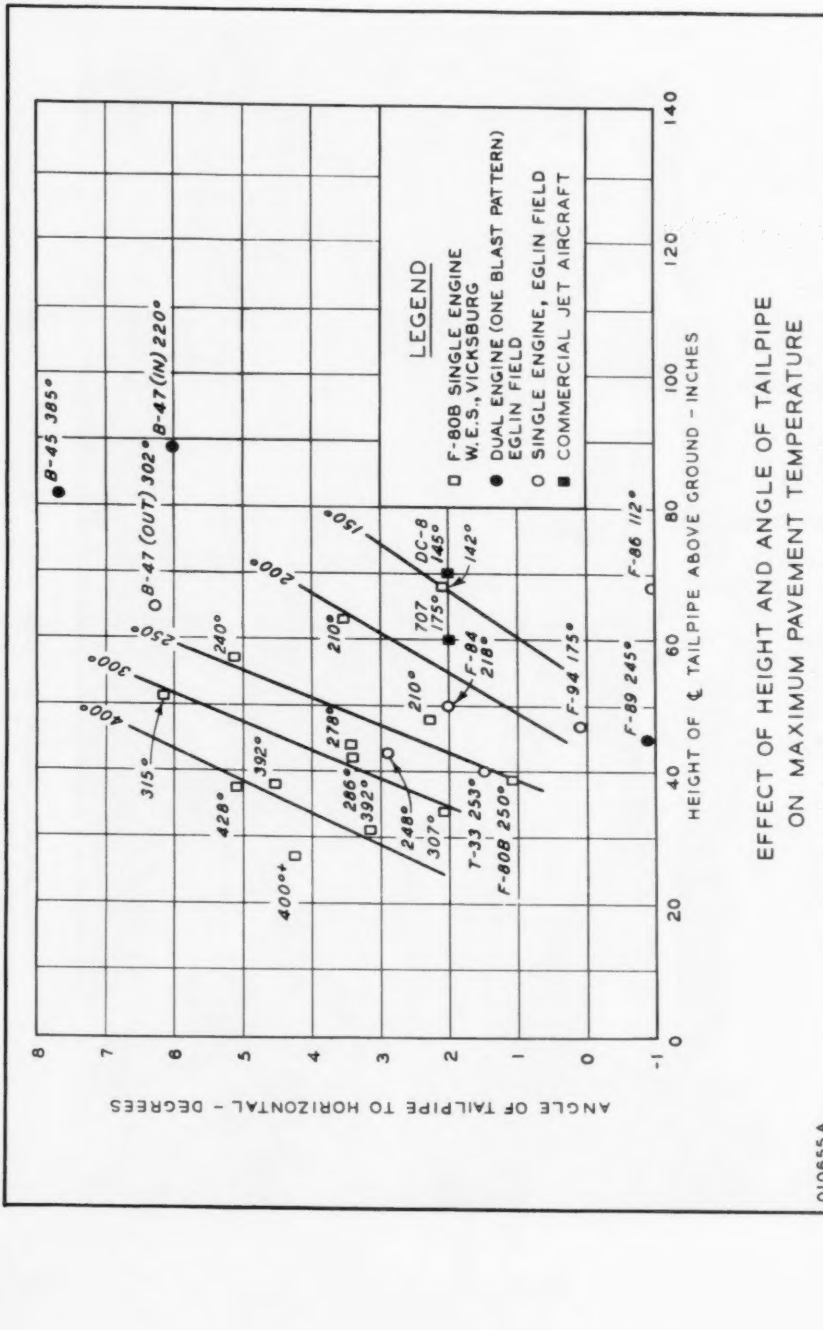

EFFECT OF HEIGHT AND ANGLE OF TAILPIPE
ON MAXIMUM PAVEMENT TEMPERATURE
LEGEND
F-80B SINGLE ENGINE W.E.S., VICKSBURG
DUAL ENGINE (ONE BLAST PATTERN) EGLIN FIELD
SINGLE ENGINE, EGLIN FIELD
COMMERCIAL JET AIRCRAFT
HEIGHT OF ℄ TAILPIPE ABOVE GROUND - INCHES
ANGLE OF TAILPIPE TO HORIZONTAL - DEGREES
0
20
40
60
80
100
120
140
-1
0
1
2
3
4
5
6
7
8
B-45 385°
B-47 (OUT) 302°
B-47 (IN) 220°
DC-8 145°
142°
707 175°
F-84 218°
F-86 112°
F-89 245°
F-94 175°
T-33 253°
F-80B 250°
400°
300°
250°
200°
150°
315°
428°
392°
286°
392°
278°
248°
307°
240°
210°
210°
400°+
010655A

Figure 1

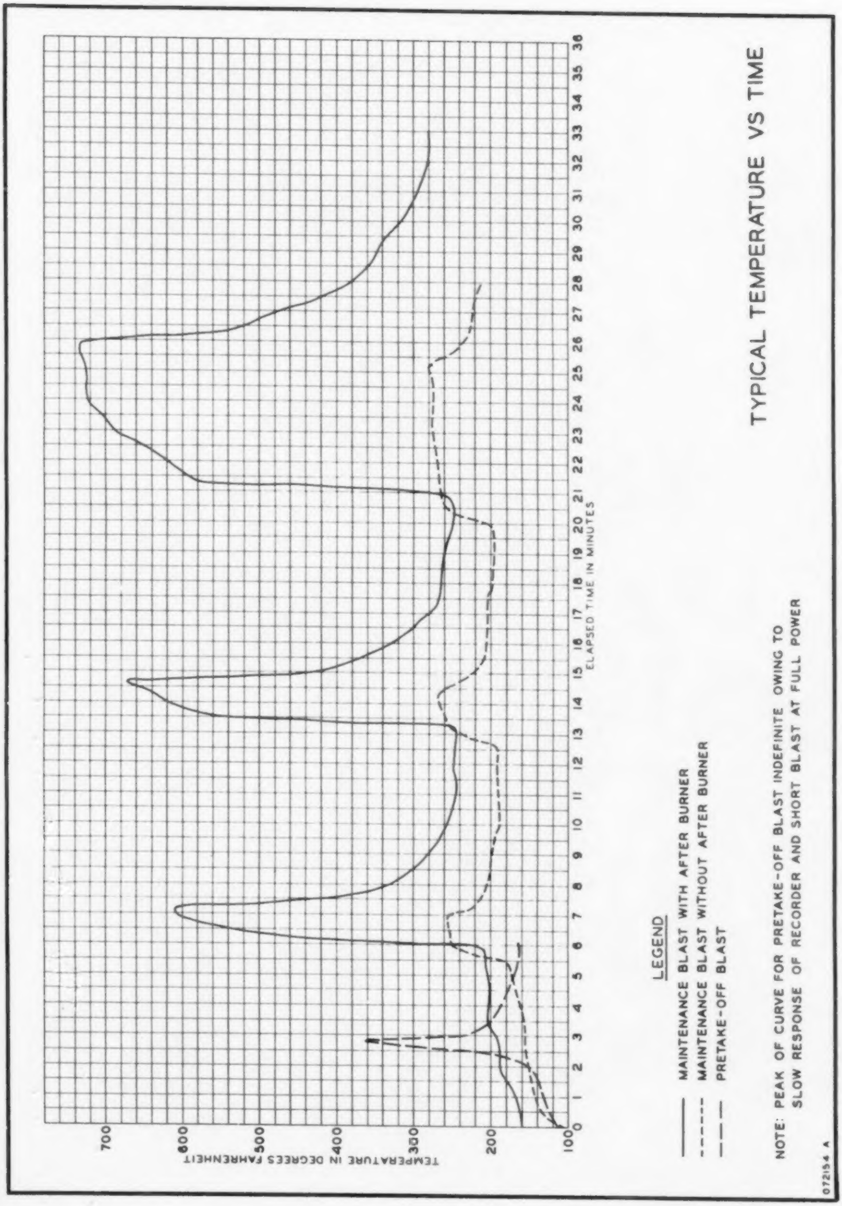

TYPICAL TEMPERATURE VS TIME
TEMPERATURE IN DEGREES FAHRENHEIT
100
200
300
400
500
600
700
ELAPSED TIME IN MINUTES
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
LEGEND
MAINTENANCE BLAST WITH AFTER BURNER
MAINTENANCE BLAST WITHOUT AFTER BURNER
PRETAKE-OFF BLAST
NOTE: PEAK OF CURVE FOR PRETAKE-OFF BLAST INDEFINITE OWING TO SLOW RESPONSE OF RECORDER AND SHORT BLAST AT FULL POWER
072154 A

Figure 2

Photograph 2. Setup for jet-fuel-spillage tests with cans simulating overflow pipes 30 in. above pavement.

Photograph 3. Condition of asphalt pavement after 13 cycles (three days) of fuel spillage.

Paper 1480 December, 1957 AT 2

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

USAF AIRFIELD PAVEMENT PROBLEMS IN THE JET AGE[a]

George W. Leslie[1]
(Proc. Paper 1480)

ABSTRACT

A brief review of the U. S. Air Force experience with airfield pavements for military jet aircraft is presented for the benefit of commercial operators who will be concerned with providing paved facilities for commercial jet aircraft. Effects of jet engine exhausts, jet fuel spillage, wheel loads and pressures, and channelized traffic are discussed.

INTRODUCTION

Had it not been for military requirements it is quite likely that the introduction of jet aircraft to the commercial field would still be a long way off in the future. But such is not the case. The jet age is here. And, in some respects, those concerned with providing adequate ground facilities are not ready for it.

Developments in military jet aircraft have been astounding. And it is not unlikely that we shall witness comparable developments in commercial jets.

No other single organization in the U. S. has had as much experience with jet aircraft as the United States Air Force. With the entrance of jet aircraft in the commercial field, airport managers and engineers will be faced with many similar problems which faced the Air Force. With this in mind it is believed well to pass on the benefits of this experience as it pertains to

Note: Discussion open until May 1, 1958. Paper 1480 is part of the copyrighted Journal of the Air Transport Division of the American Society of Civil Engineers, Vol. 83, No. AT 2, December, 1957.

a. Paper prepared for presentation at Jet Age Airport Conference, New York, N. Y., May, 1957.

1. Consulting Civ. Engr., Directorate of Construction, U. S. Air Force, Washington, D. C.

airfield pavements. Because of the many facets associated with development of airfield pavement requirements, it will be necessary to limit this discussion to a brief summary of the most important ones.

The characteristics of jet aircraft which played most prominent roles in the development of airfield pavement are these:

a. Jet fuel spillage and heat and blast of jet engine exhausts.
b. High pressure tires, with their small contact areas.
c. Heavy wheel loads, and
d. Channelized traffic.

Development of pavement criteria was and is a slow and continuing process. Data furnished by aircraft designers and manufacturers, although helpful to a degree, were not always adequate. Consequently it was necessary to study operational performances under actual field conditions. Large and small scale laboratory investigations were made. Facts had to be sifted from fiction; and educated guesses had to be made as to effects of current and improved types of aircraft.

Since 1948, the Air Force has expended in excess of $ 8,000,000 in support of a pavement investigation program. Every change in criteria had, of course, a price tag. Consequently, before a change could be implemented its impact on a construction program and scheduled mission requirements had to be evaluated.

Selection of Pavement Types

Probably no other item has been so controversial and has received such widespread attention during the past six years than that concerning the type of pavement most suitable for jet aircraft. Developments in this area took place in two phases. The first had to do with the effects of jet fuel and the heat and blast of jet engine exhaust on asphaltic pavements. The second had to do with a combination of factors including heavy wheel loads, high tire pressures and channelized traffic.

Effects of Jet Fuel, Heat and Blast

Let us look at the first phase—the effects of jet fuel, heat and blast.

At the outset of hostilities in Korea in 1950, the number of jet aircraft in the inventory was small, and ground operational experience was meager. Although there were indications that the effects of jet fuel and heat and blast might be troublesome, they did not appear insurmountable. Airfields had to be built in a hurry. Funds were limited. Designs for high quality asphaltic concrete pavement had been developed that were not only relatively inexpensive but seemed to give promise of satisfactory performance. Consequently, in early 1951 the Air Force determined that selection of pavement type would be based on lowest first cost. (Fig. 1)

Experience proved however, that jet engines dumped fuel when they were shut off or when they were decelerated. Repeated fuel spillage soon dissolved the asphalt binder and the pavement would disentegrate. These areas exposed to traffic and blast soon became worse. Runway ends were quickly burned and eroded by the hot jet blasts. Loose pavement particles, resulting from these effects, were a hazard to jet engines.

Fig. 2 is typical of asphaltic pavement damaged by jet fuel.

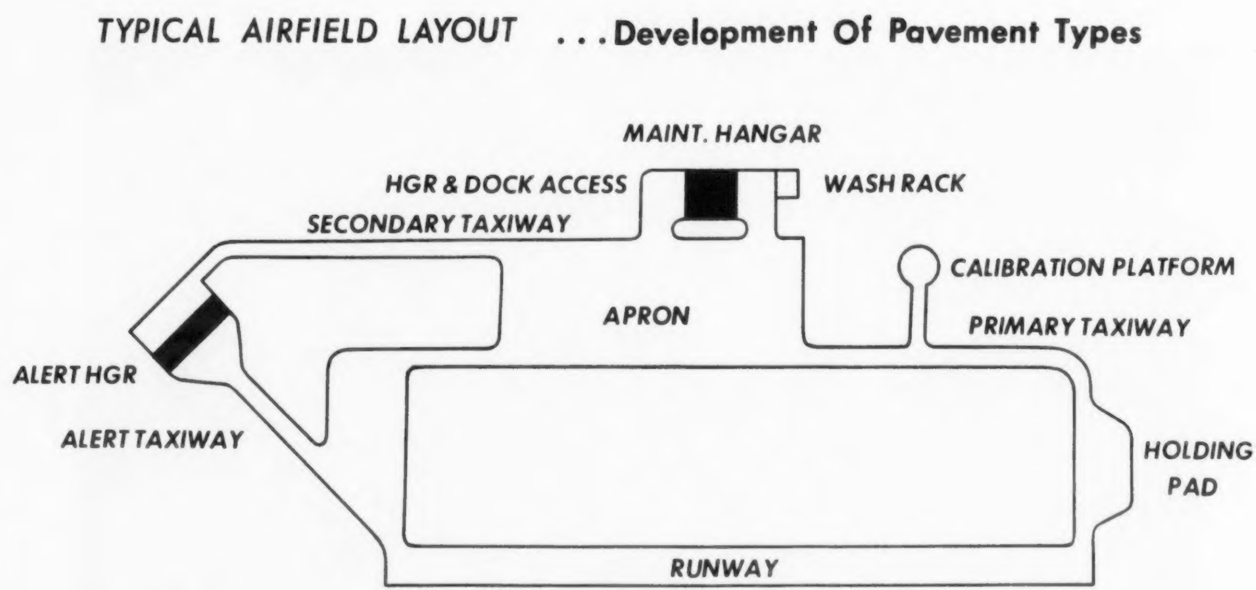


FIG. 1 Paved facilities for which pavement type was selected on basis of lowest first cost except calibration platform and wash rack .

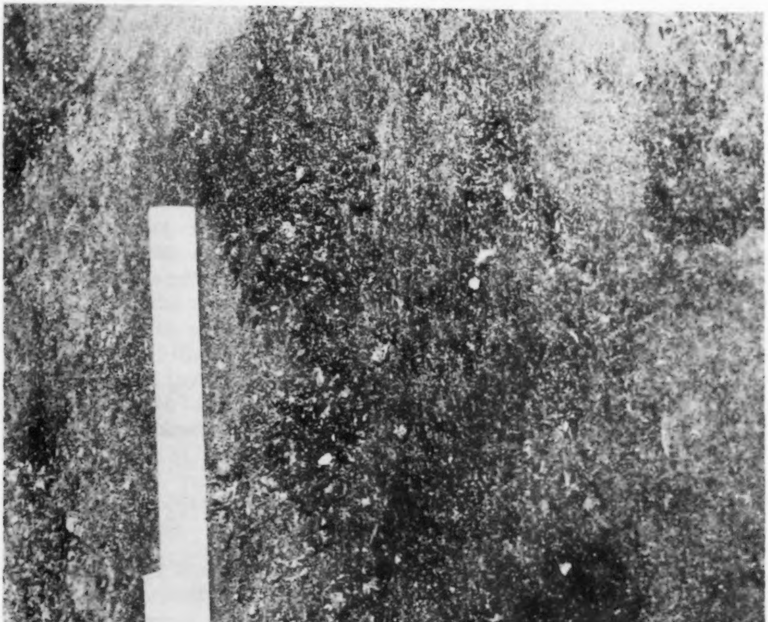


FIG. 2 Asphaltic pavement damaged by jet fuel.

Fig. 3 shows the effects of heat and blast on a runway end. Numerous proprietary products were tested in an attempt to find a suitable protective coating. Although several exhibited good resistance to jet fuel and heat, their effectiveness was limited due to the fact that they were nothing more than a thin film which could be easily damaged. They are sometimes used, however, as a temporary maintenance expedient.

By August 1952, the results of experience and tests prompted the Air Force to specify portland cement concrete pavement for so called "critical areas". These areas were defined as aprons, warm-up pads, the end 1000 feet of runways, wash racks and calibration hardstands. Criteria for critical areas remained in effect until January 1954.

Fig. 4 is a typical plan of an airfield showing the "critical areas". (Aprons, warm-up pads, runway ends, calibration hardstands and wash racks.)

In the meantime, experiments were undertaken to develop a bituminous pavement more resistant to jet fuel. The result of these experiments was a tar-rubber concrete. It was slightly more expensive than asphaltic concrete but cheaper than portland cement concrete. To test its aging qualities, it was put down on several projects on an experimental basis. Subsequently, tar-rubber concrete was selected on a competitive bid basis on a few projects as conditions seemed to warrant. But by mid 1954 its use was discontinued on new construction projects because of variable and questionable results.

During the period prior to January 1954, there were several projects on which competitive bidding on alternate types of pavement in the non-critical areas differed by only a small percentage. It was deemed prudent therefore, in the face of continuing reports of unsatisfactory performance of asphaltic pavements, to make award to the low bidder for portland cement concrete. This led, in January 1954, to a restatement of criteria for "critical areas", and included provisions for a 5% premium payment for portland cement concrete in the non-critical areas; that is, on primary taxiways and interior portions of runways. In February, a House Armed Services Sub-Committee held open hearings on the propriety of these criteria. The findings of the Sub-Committee, published in June, confirmed a requirement for portland cement concrete in critical areas, but suggested deletion of the provisions for a 5% premium allowance to obtain concrete in the non-critical areas. In August 1954, after further study, the 5% premium payment clause was deleted.

Effects of Wheel Load, High Pressure Tires and Channelized Traffic

Let us now turn to the second phase in the development of pavement selection criteria.

By early 1954, large numbers of B-47s were in the field and their peculiar ground operating characteristics, due to the bicycle type landing gear, were being demonstrated. The B-47 has a peculiar habit of porpoising. This phenomenon results from sudden changes in grade, pilot technique in landing, or in applying brakes. Because of the peculiar loading, pavement weaknesses are quickly located by the B-47 and depressions thus formed, cause them to porpoise. Once it starts, porpoising becomes more prominent and the depressions get deeper until complete failure occurs.

Fig. 5 shows the effect of B-47 traffic on improperly compacted base and sub base courses on a flexible pavement runway. Porpoising became so bad, the runway had to be closed.

FIG. 3 Heat and blast effects on a runway end.

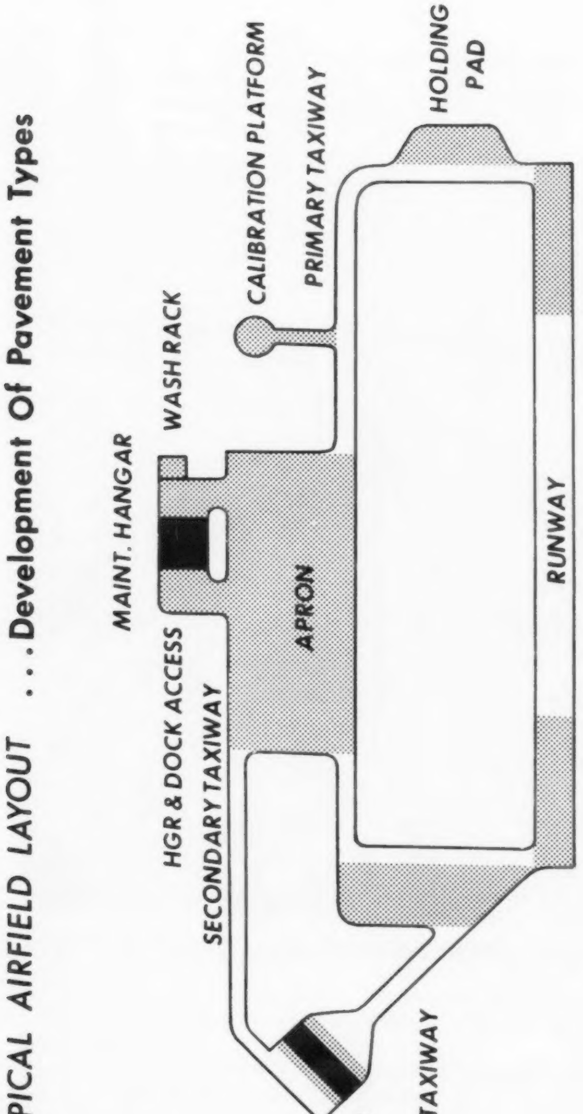


FIG. 4 Critical areas required to be paved with Portland Cement Concrete.

FIG.5 Depressions on flexible pavement runway caused by B-47 traffic.

B-47 traffic along center lines of taxiways and along taxilanes on aprons caused rutting. The repetitive loading imposed in a narrow band is the result of what is called channelized traffic.

Fig. 6 depicts the cumulative effect on pavement weaknesses, porpoising and channelizing along the center line of a taxiway by B-47 aircraft.

The effects of channelizing are demonstrated also by aircraft fitted with conventional or tricycle type gear.

Fig. 7 shows the effects of channelized B-36 traffic on a flexible pavement taxiway. The ruts are about 2 inches deep.

By early 1955, there were clear indications that it was impossible to construct a flexible pavement of uniform quality throughout its multiple layered system. Investigations proved that weakness in any one of the layers—whether it be the asphaltic surface course, sub grade, or any layer in between—would be indicated in a short time. These experiences suggested the design for channelized traffic. It amounted to thickening the center 25 ft wide portion of primary taxiways about 20%. The design applied to both rigid and flexible type pavements. However, there was still considerable doubt that flexible pavements so designed would prove satisfactory. Consequently, the Office, Secretary of Defense granted authority to specify the use of portland cement concrete for primary taxiways on an interim basis, pending results of a study to prove the new flexible and rigid pavement designs. In addition to the studies which were to be made at the Corps of Engineer Flexible Pavement Laboratory, Vicksburg, Miss., and the Rigid Pavement Laboratory, Cincinnati, Ohio, it was decided to include a test section at Kelly AFB, Texas, as part of a pavement project then under contract. Two panels —one of flexible pavement and the other of rigid pavement—were to be constructed under normal contract and inspection procedures and subjected to 30,000 coverages with a B-47 type landing gear loaded to 100,000 lbs. Both panels were to be designed and constructed in accordance with the latest Corps of Engineer instructions.

In view of the fact that it would take 10 to 12 months to complete the tests and, in anticipation of the large construction program for Fiscal Year 1956, it was necessary to take positive steps toward assuring high performance pavement. After carefully examining performance behavior of new flexible pavement under actual use, and realizing that reasonable and proven means of correction were not in sight; and after giving full consideration to the costs involved, it was determined that all primary use pavements would be constructed of portland cement concrete. Criteria reflecting this change were published in January 1956, and remain in effect today. (Fig. 8)

(Incidentally, the Kelly test was completed in July 1956. The asphaltic surface course on the flexible pavement section failed at about 9000 coverages. The rigid pavement panel successfully carried 30,000 coverages with no signs of distress.)

Subsequent traffic studies revealed a requirement to extend channelized designs to include a portion of runway ends.

Fig. 9 depicts how traffic is channelized at a runway end. (Repeat Fig. 3.)

Fig. 10 is a typical airfield layout showing the areas which are designed for channelized traffic.

(The center 25 ft of primary taxiways.

On taxiway turns, the channelized design is used for the full width.

On runway ends, the channelized design is limited to the center 100 ft width for a distance of 500 ft.)

FIG. 6 Effect of channelized B-47 traffic on flexible pavement taxiway.

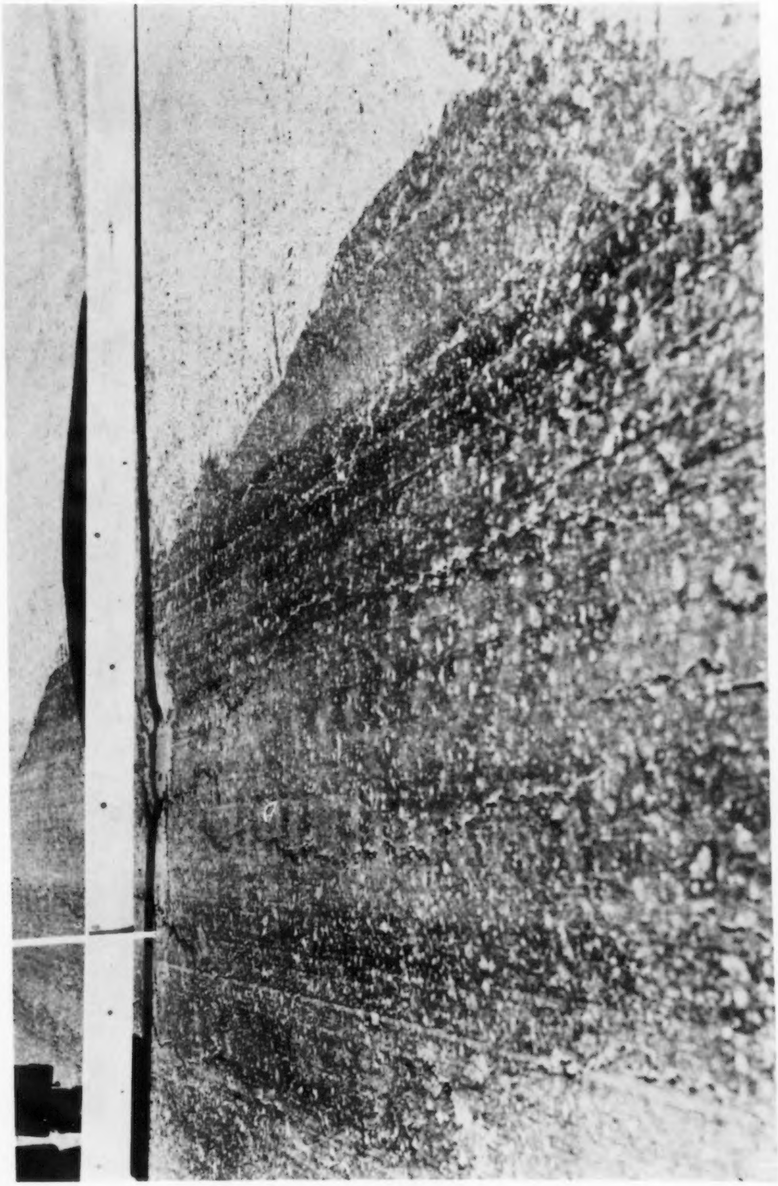


FIG. 7 Effect of channelized B-36 traffic on flexible pavement taxiway.

TYPICAL AIRFIELD LAYOUT ...Development Of Pavement Types

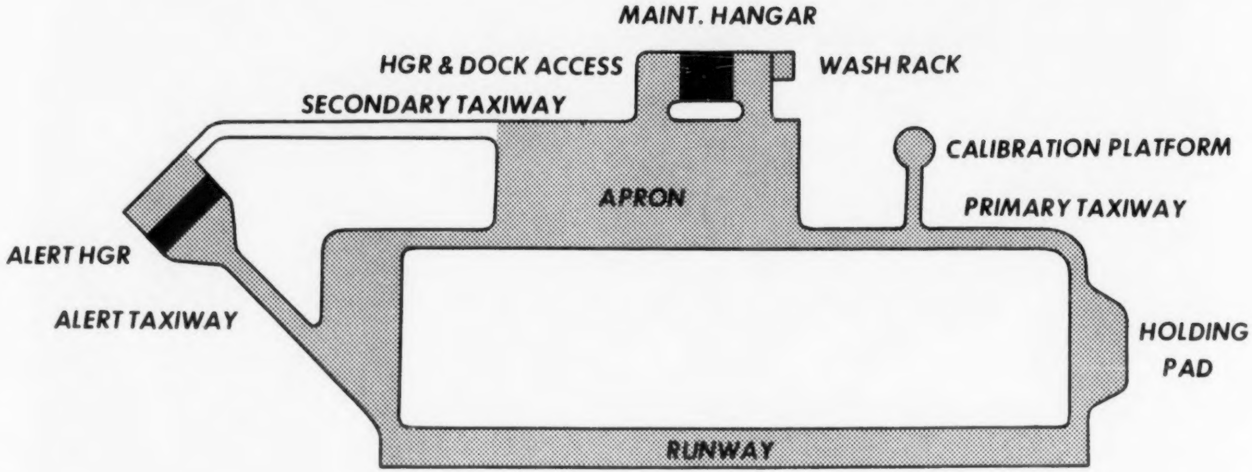


FIG.8 Primary use pavements required to be constructed of Portland Cement Concrete

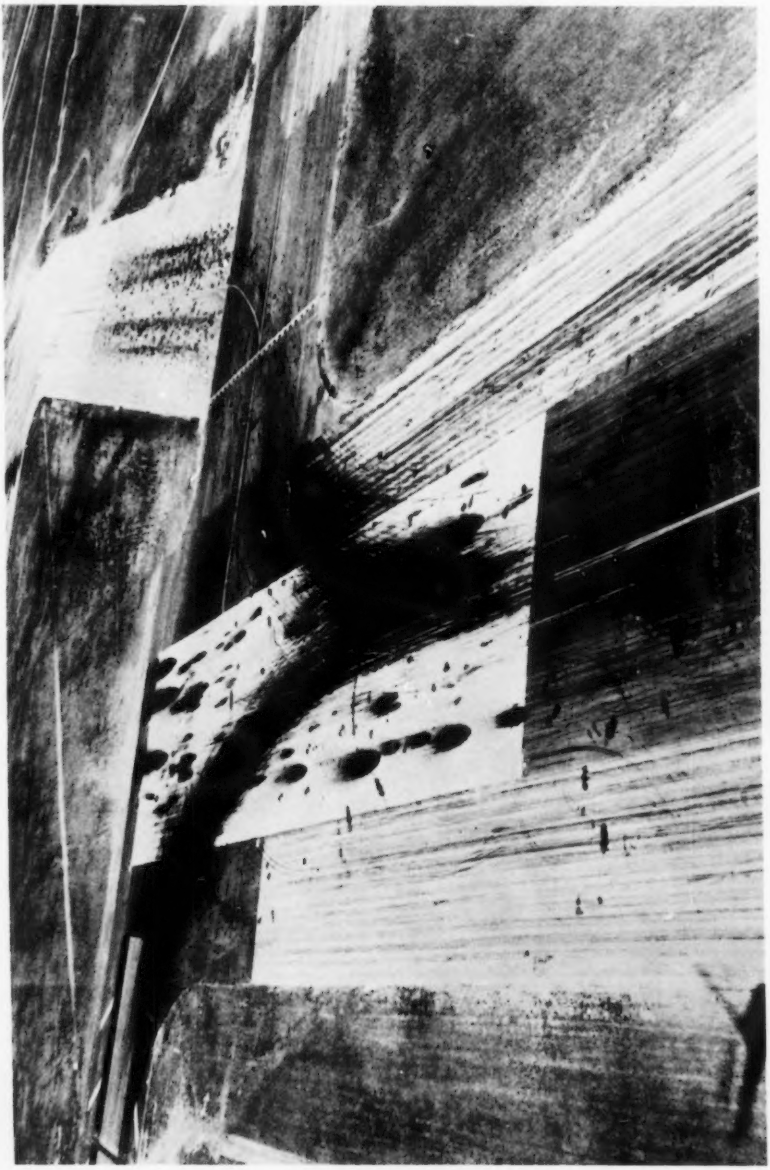
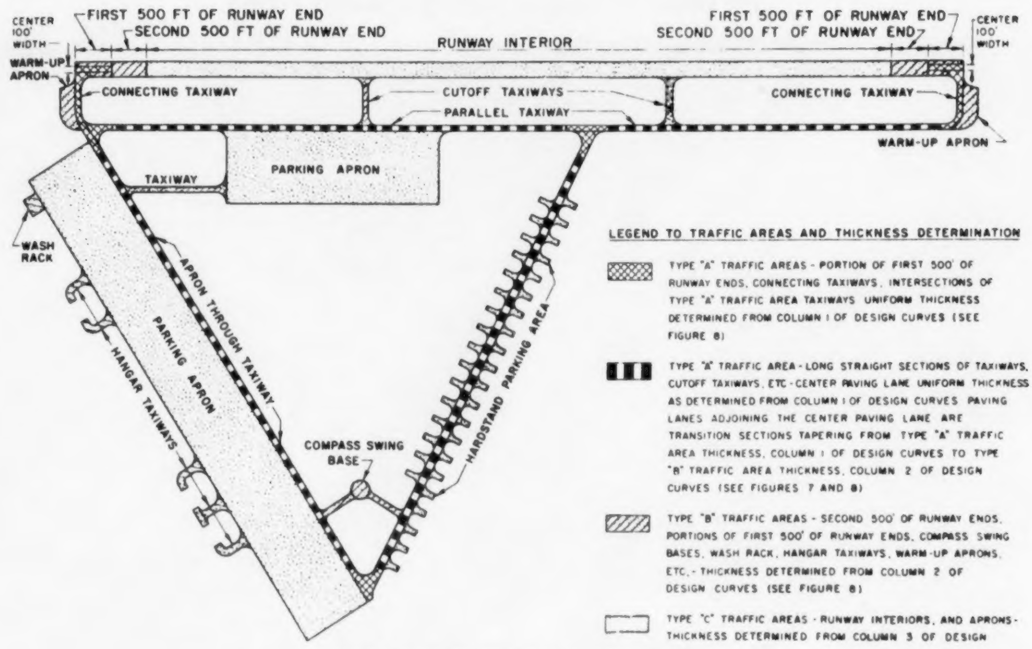


FIG.9 Channelized traffic pattern at a runway end.



HEAVY DUTY DESIGN PAVEMENTS
TYPICAL AIRFIELD LAYOUT SHOWING TRAFFIC AREAS

FIG.10 Areas designed for channelized traffic.

Design Load Criteria

Unfortunately, our pavement problems were still not solved. Aircraft were increasing in size and weight. Some of our jet fighters today weight as much as the B-17 Flying Fortress of World War II fame. Our medium bomber, the B-47, weighs five times more than the B-17. And the B-52 weighs more than 10 times as much as the B-17.

In 1950 the B-36 was our heaviest bomber. It weighed close to 400,000 lbs. We knew what the B-47 would weigh, but little was known about the successor to the B-36. It was generally conceded, however, that a bomber in the 500,000 lb class was a possibility.

With this background, plus a wealth of material gathered from design, construction and performance data on World War II pavements, it was determined to limit designs to two classes—one for fighter and medium cargo aircraft; the other to bomber and heavy cargo aircraft. This was done primarily to eliminate a multitude of designs or for designing for any one particular type of aircraft. The designs selected were (1) light load—defined as a 25,000 lb load on a single landing gear with a single wheel, the tire having a pressure of 200 lbs per sq in and (2) heavy load—defined as a load of 100,000 lbs on single landing gear with twin wheels, 37-1/2 inches center to center, and each tire having a contact area of 267 sq inches. It was believed that the heavy load design was entirely adequate for the future heavy models. Consequently, all airfield pavements for heavy cargo and bomber missions constructed from 1950 to 1956 were designed for the 100,000 lb loadings.

It was not until March 1956, however, that a change in design load due to the heavier B-52 was definitely indicated. After evaluating all aspects of the problem—take-off weights, landing weights; the number and types of operations, and operational procedures, the heavy load design was revised. Simply stated, it is a load of 240,000 lbs on a twin-twin landing gear.

How well and for how long the 100,000 lb pavements will hold up under B-52 traffic, no one can tell. But there is no doubt that there will be some major repair or re-construction projects in the not too distant future. The design and construction problems to be encountered, and the costs involved in strengthening these pavements to the new heavy load design, are cause for serious concern.

This one problem is mentioned to show the need for close coordination between aircraft designers and designers of airfield pavement. It cannot be stressed too strongly.

Operators of commercial fields will be confronted by the same problem. There is no doubt that commercial jet aircraft will continue to get heavier. And, unless the aircraft designer is not careful, there will be few present day commercial airports which will be capable of supporting these heavier craft except by fitting them with multiple wheel assemblies so as to reduce the unit load on the pavement. And this is not an easy task for the aircraft designer.

Other Pavement Requirements

Blast Pads and Paved Shoulders

Let us examine a few other miscellaneous developments in pavement requirements for jet aircraft. The blast of jet exhausts quickly erodes

unprotected grounds areas beyond pavement edges. Soil is blasted out. Grassed areas are denuded. Pavements become littered with debris. And the debris, when sucked into a jet intake, damages the engines.

Fig. 11 shows how the outboard engines of a B-47 erodes unprotected shoulders of a taxiway. The taxiway is 75 ft wide.

To protect these unstable areas, and to help reduce debris on pavements, two schemes were developed. At fighter bases, 2 inches of asphaltic concrete are placed on taxiway shoulders at turns, on the shoulder of warm-up pads, and on 150 ft of the overrun area at runway ends. These are called Blast Pads.

Fig. 12 Blast pads at a fighter base.

At bomber bases, additional precautions had to be taken. In addition to shoulder blast protection along both sides of taxiways and the outside shoulder of warm-up pads, there was the problem of providing a stable surface to support the outrigger gear of B-47s and B-52s. This was solved by paving shoulders of taxiways, warm-up pads and aprons.

Fig. 13 Shoulder paving at a bomber base. The pavement is of flexible type construction designed to support a single wheel load of 10,000 lbs. At B-47 stations the paved width of shoulder is 25 ft. At heavy bomber stations the paved width is 50 ft.

Power Check Pads

Special test facilities had to be provided for performing engine maintenance tests. These are generally a concrete pad located at some distance (usually 3000 ft) from inhabited areas because of the noise. Blast fences or deflectors are provided to eliminate soil erosion and dust.

Blast Deflector (Fig. 14)

Recently, blast deflectors have come into more prominent use on aprons between parked aircraft, or off apron edges. It is very likely that blast deflectors may be a requirement on aprons and loading ramps at civil airports to protect nearby aircraft, surrounding facilities, personnel and passengers.

Stabilized Overruns

A doctrine of long standing among airfield engineers and planners is that runways are designed wide enough and long enough to accept the most critical aircraft operating there from. Consequently, there was nothing much beyond a runway end except a graded area—provided there was room. The Air Force prescribes that this area be 1000 ft long and as wide as the runway plus shoulders. Occasional damage to aircraft—usually a washed out landing gear—was generally accepted, if the pilot was unfortunate to land short or to over shoot. Jet aircraft, however, presented a more serious problem. Their high landing speeds, long landing rolls, small wheels and high tire pressures require that some degree of strength be built into the overrun areas. The Air Force now requires overruns to be stabilized. However, the width of the stabilization is limited to the paved runway width. Actually, the stabilization is designed as a flexible pavement for either light load or heavy load design criteria, as the mission dictates, but it is calculated on emergency use conditions; that is, a minimum number of coverages. It results in a pavement structure about half as thick as that of the standard capacity-use design.

FIG.11 Outboard engines of a B-47 causes erosion of unprotected taxiway shoulders.

TYPICAL AIRFIELD LAYOUT . . . Development Of Pavement Types

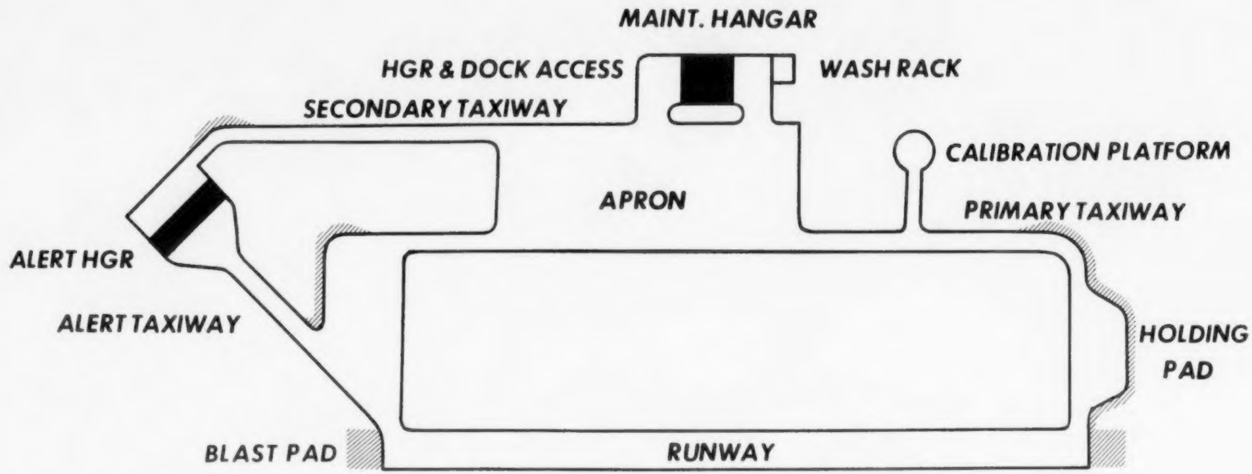


FIG.12 Areas of shoulders at fighter bases which require 'blast pads'.

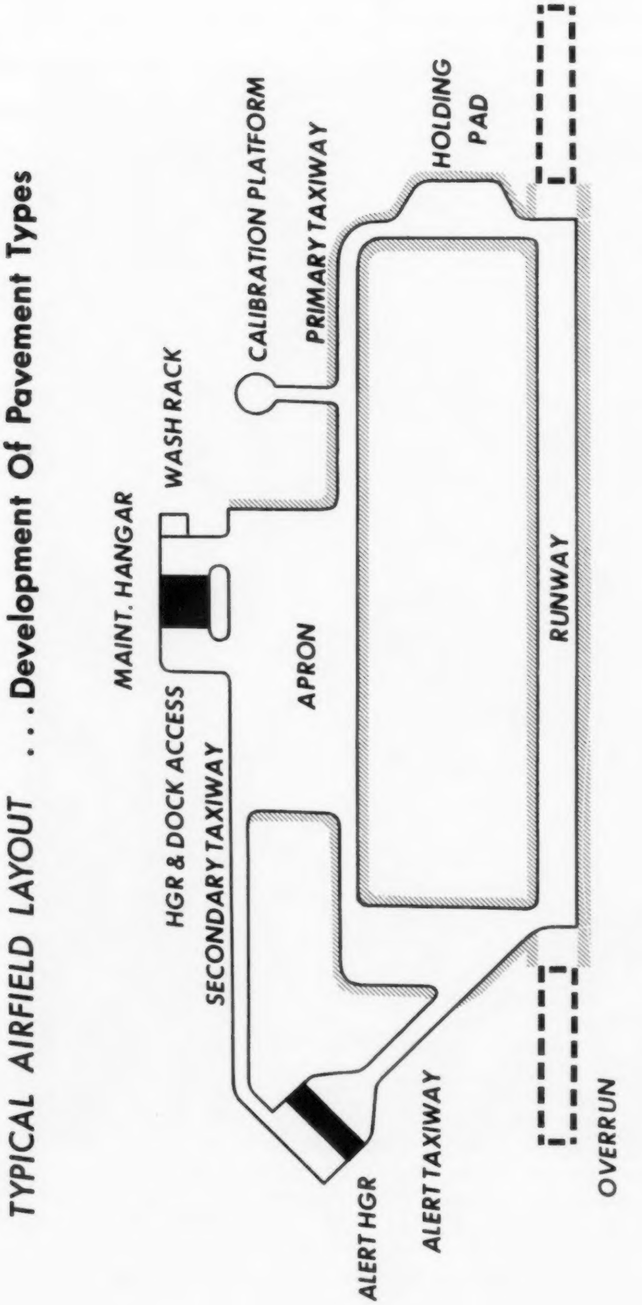


FIG.13 Stabilized shoulders at a bomber base.

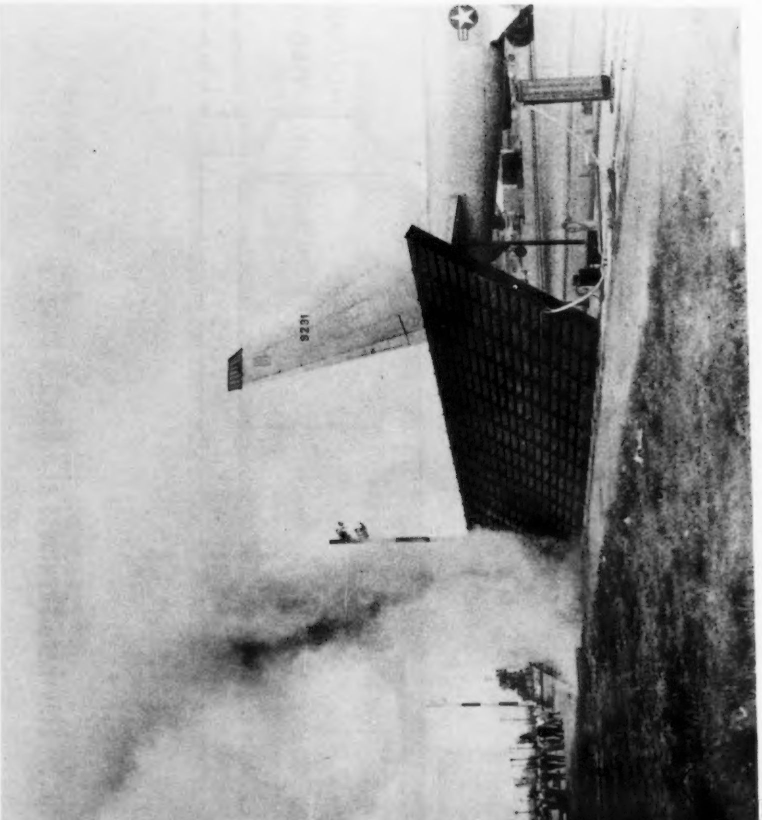


FIG.14 A blast fence deflector developed by Boeing Airplane Co.

The surface is given only a double bituminous treatment and stone chips. This type of construction for runway overruns is relatively inexpensive and can be easily maintained. The biggest advantage, of course, is that it minimizes injury to pilot and damage to aircraft.

Overrun Barriers

Another innovation, along with stabilized overruns, is the overrun barrier. It is an adaptation of the barrier used on aircraft carriers. It is normally placed on an overrun, just off the runway end to stop fighter aircraft in the event of an aborted take-off or long landing roll. Barriers have proved very effective in saving the lives of pilots and in preventing serious damage to aircraft.

Damage to Jet Engines by Foreign Objects

Another serious problem was that of jet engine damage by foreign objects. This problem is still unsolved. Repairs to jet engines damaged by foreign objects is costing the Air Force approximately $15,000,000 each year. As is well known, debris can be carried onto paved surfaces by wind, rain and vehicles and by the man on foot. Bolts, nuts, wire, tools and any number of other types of metallic objects may be found on the pavements. These and pavement particles are potential hazards to jet engines. It became necessary to indoctrinate all personnel in improved housekeeping habits. Pavements have to be constantly inspected and swept, or flushed clean. In many cases commanders have had to resort to sweeping pavements by hand broom. Unfortunately, the rotary type broom sweeper in common use today is quite ineffective. A positive action vacuum type sweeper has been developed and is now in pilot production. It is a large piece of equipment and therefore its use will be limited to large open areas. There is still a need for a small pick up sweeper which can be manuevered close to parked aircraft.

Maintenance

While the AirForce was researching pavement requirements and design, pavement construction was proceeding at a rapid pace. From 1950 to early 1956, approximately 116,000,000 square yards of new pavement were constructed—a capital investment of $850,000,000. In addition, the inventory includes hundreds of thousands of square yards of World War II construction which are substandard. Consequently, very few pavements meet all present day requirements.

Trying to maintain substandard pavement in satisfactory condition is almost an impossible task. For the Installations Engineer, it is a most frustrating one. Seldom is he equipped with, or has access to, the right kind of equipment and materials, or has sufficient skilled and technically qualified personnel to do the job. And, because most Air Force installations are one runway complexes, flight-operations usually cannot be shut down without seriously affecting the base mission. For example: suppose repairs at one of these bases are withheld until the flying unit takes off on a temporary assignment. This is not an unusual procedure. The Installation Engineer has been preparing for months to have everything ready. The unit moves, but

the weather turns bad and the repairs cannot be made. As time goes on conditions get worse. Subsequently, the field has to be shut down. Aside from the additional expense to perform major repairs or reconstruction, there is the cost of moving the flying unit and its supporting elements to another base for several months—perhaps even a year.

Repairing asphaltic pavements which have been damaged by jet fuel or blast is a never ending problem and will never be licked until the pavements are replaced with portland cement concrete. Some of the old rigid pavements, although structurally sound, have badly scaled and spalled surfaces. These conditions contribute to jet engine and tire damage. It appears now that a solution to this problem has been found. A method of applying a thin bonded concrete overlay has been developed that shows considerable promise.

The point of this discussion is to stress the need for the best design and highest quality construction from the very beginning in order to maintain the highest degree of combat readiness which the Air Force is obliged to do in the performance of its mission.

In recognition of the fact that nothing man-made is free from defect for any length of time, pavement repairs for today's jet aircraft must be of the same high quality design and construction as the original product. Maintenance engineers must be highly qualified. It requires highly skilled technicians and laborers; the right kind of equipment and materials; and, last but not least—money.

Investigational Program

Although the Air Force has come a long way in developing operationally suitable pavements for jet aircraft, there are many problems which remain unsolved, and it can be expected that many other problems will present themselves as new types of aircraft become operational. To solve these problems and to stay abreast of aircraft developments requires an investigational program of broad scope.

As in the past, the principal item of investigation is that of pavement design. As aircraft have increased in size and weight, pavements have become thicker. The 6 or 7 inch concrete slab, which was suitable for World War II bombers, is not thick enough for many of our present jet fighters. A slab 10 to 11 inches thick is now a minimum. Heavy bombers today require concrete slabs 18 to 22 inches or more in thickness.

Flexible pavements have also increased in thickness. But a limit seems to have been reached in the design and construction of a bituminous pavement mix, which can satisfactorily support the heavy, concentrated wheel loads of today's military jet aircraft.

Every step of the way, from the initial subgrade explorations through design and final finishing of the end product, demands meticulous control. These requirements, coupled with the greater quantities of materials and the rising costs throughout industry, result in construction costs of staggering proportions.

The investigation program is geared to solve these problems; not only as they apply to new facilities, but also to improvement of existing facilities.

The program for this year includes such items as prestressed concrete, reinforced concrete and cement treated bases. Plans are already under way to incorporate some of the recent developments in test sections at an Air Force installation.

The important part that the aircraft designer can play in this game should not be overlooked. If he and the pavement designer work together on these problems, there is every reason to believe that reasonable and economical solutions will be reached.

CONCLUSION

During the brief period that the Air Force has been determining pavement requirements for military type jet aircraft, there are certain facts which stand out and which cannot be ignored.

Pavements must be unaffected by the solvent action of jet fuels. They must be heat resistant to withstand the hot, high velocity exhaust of jet engines. They have to be abrasion resistant, durable and structurally adequate to support heavy wheel loads, and to withstand high unit contact pressures and high frequency loadings.

Based upon its experience with design, construction, and service behavior of airfield pavements, the Air Force has concluded that these requirements can be most nearly met by the use of portland cement concrete.

Jet engines, although tremendously powerful, contain finely balanced, delicate parts, which are easily damaged by foreign objects sucked into their intakes. All pavements must, therefore, be kept clean. This requires an intensive personnel indoctrination and housekeeping program. In order to alleviate the dust problem and the spread of debris on the pavements, shoulders adjacent to taxiways, aprons, warm-up pads and areas at runway ends must be stabilized with an erosion resistant surface.

Finally, recognition must be given to the fact that modern aircraft, both military and civil, are rapidly becoming faster, larger, heavier and more numerous. Pavements must be adequately designed and constructed to meet the requirements, not only of present aircraft, but also those which can reasonably be anticipated in the future. Unless due allowance is made now for future increases in loading, pavement maintenance and repair problems will reach enormous proportions. Indeed, this situation actually faces us today because the rapid growth of today's aircraft was not fully anticipated. In some cases we are experiencing disruption of flying operations, a factor which must be considered when totaling up the cost of pavement repair or strengthening projects. It is very essential that aircraft designers and airport planners work hand in hand so that all will be fully aware of the problems with which each must contend, both now and in the future.

Paper 1481 December, 1957 AT 2

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

THE JET AGE AIRPORT AND ITS NEIGHBORS[a]

Charles E. Rosendahl[1]
(Proc. Paper 1481)

SYNOPSIS

Based on five years' experience in airport community problems created by piston engine aircraft operation, the author makes projections on airport community problems incident to civil jet aircraft operations. Noise and vibration problems in the vicinity of air terminals will change as jet aircraft are introduced. Early community opposition to civil jet operations was based on unsuppressed, after-burner equipped, military aircraft.

When it was first announced that commercial airlines had ordered jet aircraft, an immediate wave of speculation, rumor, conclusions unsupported by fact and demands for restrictions on civil jet operations flooded the press and became priority discussion items in airport communities. All of this outcry took place before any of the people concerned had opportunity to hear or see an American civil turbo-jet transport in action. All of the alarm and demands for restrictions were based in the public's experience with the military jet—an aircraft operating with afterburners and without noise suppressors.

Even today, only a handful of airport neighbors have seen or heard a civil turbo-jet transport. The Caravelle and the Boeing 707 briefly visited some of our airports. The Douglas DC-8 and the Convair 880 have yet to fly. The M 707 prototype has not yet flown with suppressors.

However, the human being is a confounding species. He likes to talk about the obscure and the unknown. Humans are inclined to become experts with alacrity, critics with intensity and believers with timidity. And with civil turbo-jet transport operations still more than a year off, we find the airport neighbor in rather poor psychological condition as he awaits the event. Like a patient awaiting a tooth extraction by a strange dentist, amid the pained outcry of his predecessor in the chair.

Note: Discussion open until May 1, 1958. Paper 1481 is part of the copyrighted Journal of the Air Transport Division of the American Society of Civil Engineers, Vol. 83, No. AT 2, December, 1957.

a. Presented at The Jet Age Airport Conference, May 15-17, 1957.

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This is an unfortunate situation. It is unfortunate for the civil air industry because it is making difficult the important task of obtaining maximum public support for the jet transport. It is certainly unfortunate for the millions of airport neighbors because, like the dental patient, they may well find that the anticipation of the dental work was far more trying than the work itself.

It is incumbent upon all of us interested in our country's continued air age leadership to do what we can to correct this present sorry state of affairs. Its correction requires that we make every effort to provide the airport neighbor with facts. We must discuss the problem with him frankly, fully, and dispassionately. It is a physical problem and must be approached rationally.

The civil aviation industry cannot do this job alone. To help the airport neighbor achieve a balanced perspective of his role in the jet age, we must have help. The Industry must have the help of community leaders who, after acquiring an understanding of the problem, will use their leadership to transmit that understanding to others. We must have help from the airport neighbor himself in the form of an objective, open-minded attitude on the problem until all the facts are presented. And most important, we must have continued help from the Press and other media of mass communication. As we know, many people form their opinions and reach conclusions largely on the basis of what they read, see and hear through these media. A balanced, fair, factual presentation by such media is essential to the attainment of our objective.

The Press of this area is to be commended for its handling of the recent Caravelle demonstration flights. Published reports contained both the favorable and unfavorable reaction from the airport neighbors. Too frequently, one hears only from the critics.

So much for the past and present. In trying to visualize the future effects of jet transport operations on the airport community, we must consider five factors. These are:

1. The runway configuration at the airport.
2. The nature of the airport surroundings.
3. The character of the actual noise characteristics of the aircraft in scheduled service.
4. The anticipated volume of operations.
5. The manner in which the aircraft will be operated.

Before briefly discussing each of these, I would like to give all possible emphasis to one point—the noise characteristics of the aircraft constitute only one factor in this situation. This is true whether the noise is suppressed or unsuppressed.

In the past Industry thinking has been concentrated on the suppressor development program, to the exclusion of the other factors involved. While effective suppression of the noise will obviously contribute to obtaining community support for jet transports, the Industry is certainly not putting all of its eggs in the suppressor basket.

Suppressor development is progressing rapidly. The civil turbo-jet aircraft will be equipped with suppressors when it goes into service. But it is most important to keep this factor in proper perspective. It is a part, but only a part, of the over-all effort for operating aircraft with a minimum of disturbance to the airport neighbor. Consider the five points enumerated above.

The first point is runway configuration. This is going to be an important factor. The judicious use of runways is an effective means of reducing the noise disturbance to communities near the airport.

Secondly, the nature of the airport surroundings is another key factor in developing effective noise abatement procedures. The location of existing open areas and waterways, industrial plants, and the size and population density of residential areas, all must be carefully evaluated.

The important thing here is that these factors will vary from one terminal area to another. Thus, while this is a problem of national scope, it breaks down into a number of local terminal area problems, Each susceptible to individual treatment.

The whole jet noise picture is neither all black nor all white, as some have a tendency to paint it. Before the extent of the problem can be accurately assessed—in any given area—a good hard look at that particular situation must be taken, and appropriate operations plans must be developed. This refers, of course, to noise abatement procedures which in no way compromise flight safety, and which are completely compatible with air traffic control procedures as prescribed by CAA.

Next, there is the single factor which, to date, has received all of the attention—the noise characteristics of the aircraft. This is not a simple subject to discuss. Jet aircraft present a <u>different</u> aircraft noise from that which any airport neighbor has ever experienced on a regular basis.

It is a fallacy, therefore, to get into the semantic trap of describing the outside noise characteristics of jet transports as "comparable" to those of present day aircraft. It would be equally fallacious to rely solely on decibel readings as the criterion for the acceptability of the noise. Admittedly, the jet transport purchasers had to use some frame of reference when they were writing their noise specifications. They used the obvious comparison with present day aircraft noise. For contract writing, this is fine. But out in the community at the end of a runway, comparisons with present noise and with decibel readings are but part of the story.

The airport neighbor is going to have a new noise experience, and he probably isn't going to like it in the beginning. Its very newness, at the start, is going to attract attention which may not be warranted by the sound volume. As the airport neighbor gains experience with jet noise, his attitude toward it is going to change. Whether the change will be for better or for worse, only time will tell.

Indications to date are that the jet transport engine will produce more of a rumbling noise than a pulsating one. This might prove to be an advantage. Many airport neighbors specify that the pulsating noise of the piston engine is its most objectionable feature. That pulsating characteristics also tends to set up the vibration effect which many people dislike.

There will be other differences between piston engine noise and jet engine noise. The jet engine will produce noise in both the high and low frequency ranges. Generally, it is the low frequency noise that is considered the more objectionable. The high frequency portion of the noise attenuates or dissipates into the air much faster than the low frequency portion. Also, the high frequency noise does not penetrate structures as much as the lower frequencies. The suppressor may, by taking energy out of the low frequency noise, convert some of it to higher frequencies, frequencies often inaudible to the human ear. However, the high frequency compressor whine will be another new noise factor and may, particularly on approaches for landings, present a problem during its initial appearance in the airport area.

The speed of the jet aircraft will also affect the community noise situation. The jets will move faster. This means, obviously, that the duration of

exposure to the peak noise at any given location will be shorter than at present. Furthermore, since the low frequency part of this jet noise emanates from the rear of the engine, after the aircraft has passed the observer, he will hear that noise for a while, but in rapidly lessening volume because of the speed and distance factor. We can expect that communities several miles from a terminal, which now occasionally find piston engine noise objectionable, will have no problem with jet noise whatsoever. This is expected because of the outstanding climb capabilities of the jet aircraft, once it has attained sufficient forward speed.

I think we should be perfectly clear on this matter of the jet climb and community noise. In all probability, the climb will not materially help those living close into the terminal. The other factors mentioned will serve noise abatement in close-in areas.

The fourth factor in the noise situation will be the volume of operations by jet transports. There are two considerations here. One is the number of aircraft in operation in a given area during a given period. The second is the frequency of operations by any given individual aircraft.

As to numbers in service, jet aircraft will not replace piston engine craft overnight. The advent of the new jet transports will be spread over an extended period.

This is a heartening prospect for several reasons. There will be no sudden onslaught of jet noise. The number of jet aircraft will increase gradually and will not be large, compared to total aircraft in use, for some time. Most important, we will have an opportunity to learn a great deal about operating them in the best interests of the neighbors, long before the total deliveries have been made.

Realistically, however, our operations volume will be swelled by the individual aircraft usage factor. At five million dollars apiece, these aircraft are going to be given a maximum amount of work by their purchasers. Their speed will also permit a greater number of operations per aircraft. On schedules now being served on a round-trip-daily basis by present aircraft, we may well see the jets almost doubling that performance. It seems probable, therefore, that airport communities will see the same particular jet aircraft more frequently than he sees any other aircraft today.

On the whole, the volume factor due to increased numbers and increased individual utilization does not appear to be a critical one for the immediate future. This is quite an important consideration, because our experience proves beyond question that a high volume of operations compounds the noise problem. Thus it is during our peak traffic periods that the airport neighbor is most sensitive to the noise condition.

Finally, the over-all community relations situation in the jet-age airport neighborhood is most certainly going to be influenced by the manner in which the aircraft are operated in the terminal area.

Fortunately, the Industry through NATCC has had five years of intensive experience in this very complex matter. This experience is going to be invaluable as we tackle the problem of getting our jets into and out of the terminal area with a minimum of neighborhood disturbance. We have learned that pilot technique during approaches and takeoffs, runway usage, wind velocity and direction, weather conditions, traffic control procedures, the availability of adequate taxiways, and a number of other factors, all play a vital role in reducing aircraft noise disturbance to the airport neighbor.

We have also found that a trial-and-error method is the only way to

develop procedures which will achieve maximum results. Time and again, we have worked out a procedure on paper, only to find that then it was flight tested, it required modifications. If this has been true with conventional aircraft with which we are intimately familiar, it is certainly going to be true with the new jet transports.

Therefore, it is useless at this time even to attempt to specify just what noise abatement flight procedures may be used. It is completely safe to say, however, that flight safety will be the only limiting factor in the development and implementation of every possible method for conducting jet operations with a minimum of disturbance to the airport neighbor.

In conclusion, it is evident that the neighbor of the jet-age airport is far more fortunate than his predecessors in the airport vicinity, in one very important respect.

Ten years ago, little or no thought or attention was being given the problem of conducting air terminal operations on a good-neighbor basis. Absolutely no thought was being given to outside noise characteristics in aircraft design.

Today, in behalf of its jet-age neighbors, the entire Industry—from manufacturing president to flight crew—is alert to the problem and determined to do everything possible to solve it. This effort will not stop with only the installation of suppressors on the engines.

It will not stop until, airport by airport, the best technical brains at our disposal have exhausted every possibility for combining the unlimited promise of the jet age with every consideration for the airport neighbor.

Paper 1482 December, 1957 AT 2

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

FUELING U. S. AIR FORCE AIRCRAFT[a]

George B. Seeley[1]
(Proc. Paper 1482)

There appears to be some misunderstanding regarding the actual relation of the U. S. Air Force to other Department of Defense agencies. The U. S. Air Force is an independent and autonomous military institution separate and distinct from the Departments of the Army and Navy. It operates in coordination with the Army and Navy military services for defense purposes. Coordination in military matters is effected by the Joint Chiefs of Staff for Air Force, Army, and Navy. The Chiefs of Staff are under the direct authority of the Secretary of Defense in cooperation with the Secretaries of Air Force, Army, and Navy. The Army and Navy have individual air forces which are organized specifically to their requirements and which should not be confused with the overall functional requirements of the U. S. Air Force as an independent fighting organization.

The U. S. Air Force chain of authority extends from the Air Force Chief of Staff at Washington through the major air commands to Air Force strategic, tactical, training, research and development bases associated with these specific mission requirements. The writer's position is in the office of Assistant Chief of Staff, Installations which organization is charged among other duties with providing policy and criteria for the construction of air bases and related facilities. The writer's specific work concerns criteria for designing liquid fuels storage and dispensing facilities. The writer will, therefore, try to present a general picture of the problems and actions to provide suitable liquid fuel facilities for fueling the military aircraft.

With a little study everyone will realize that the fueling of military aircraft is and always has been an important feature of the flying operations because just like an automobile, an aircraft will not go without fuel.

To help in this presentation, the writer will take you back to the early days of aircraft fueling and give you the stages in the development of fueling facilities for the Air Force. Back in the 20's it was apparent that in order to meet military operating requirements it would be necessary to bring the fuel to the parking apron near where the aircraft were parked. Basic engineering made it appear that delivery by pipeline would be the most efficient method.

The first fueling system adopted was the old so called hydraulic system

Note: Discussion open until May 1, 1958. Paper 1482 is part of the copyrighted Journal of the Air Transport Division of the American Society of Civil Engineers, Vol. 83, No. AT 2, December, 1957.

a. Presented at the Jet Age Airport Conference, May 15-17, 1957.

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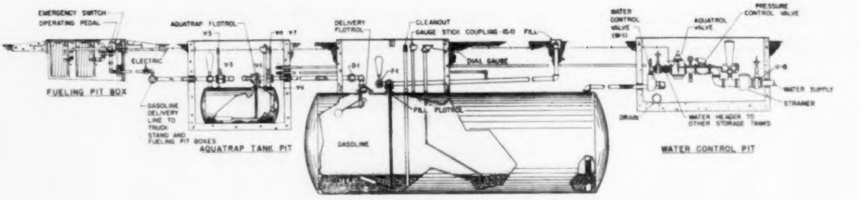

Fig. 1.

that moved the fuel by water pressure. (Fig. 1). The sectional view shows the basic equipment used and its relative relation in the system. Fuel was stored in underground pressure tanks that were always full due to water in the bottom (this eliminated vapor, a very desirable safety feature). By applying water pressure the fuel flowed through the pipe out to the fueling pit at the apron edge. The pit had two meters and two hoses on reels. This system was capable of fueling at 60 GPM from each hose or a total of 120 GPM, into the top of the fuel tanks in aircraft wings. This method required the use of as much water as fuel delivered. This was not a serious problem with the small quantity of fuel used at that time.

In the 40's the development of large aircraft made it apparent that more rapid fueling would be necessary to complete the delivery of 25,000 gallons of fuel into the B-36 aircraft within an acceptable time limit. An extensive investigation of several ideas for a radical change in fueling operations was made in the late 40's. It was concluded that a fueling rate of at least 600 GPM would be required to meet the time factor. This presented a different problem with a larger water requirement, so it was decided that pumping the fuel would be more desirable. Considering the high pumping rate and the storage necessary to provide the fuel for the 600 GPM rate it became apparent that at least 50,000 gallons of operating storage would be required. The 50,000 gallon horizontal cylindrical tank was adopted due to the fact that it could be shop assembled in two halves and shipped by rail or truck. This provided an economical storage tank both in time and money saved. In order to eliminate vapor problems in pumping, the deep well turbine type pump was adopted so the fuel would be pushed rather than lifted. It was agreed that the fuel would have to be pumped into several tanks in the aircraft at the same time with the 600 GPM flow rate. To accomplish this the piping manifold within the aircraft was connected to a single inlet point. The fuel would be supplied into the aircraft at 600 GPM by a connection to this single point.

This fueling rate presented a serious problem in the equipment field as there was very few items available capable of operating at 600 GPM with aviation fuel. The various manufacturers were very helpful in developing suitable equipment as soon as we informed them of our requirements. A water

separator capable of removing water from aviation gasoline at a 600 GPM pumping rate was not available. This equipment had to be developed while the fueling systems were being designed. The first models did not meet requirements when placed in operation. As each model was developed new features were added to meet the safety needs. Another very necessary item was the fueling outlet valve. It was first thought that the existing 120 GPM valve could just be enlarged to handle 600 GPM. Due to the larger contact surface and increased pressure this did not prove satisfactory. Many improvements were necessary before a usable item was made available.

It was decided that for military reasons the fuel must not all be stored at one location on an air base. To meet this requirement in designing the fuel system several operating storage tanks were to be located at various sites. This would provide for large fueling capability at several locations even though one group of operating storage tanks were out of commission due to power failure or military action. This decision was an important factor in deciding that a pressure fueling system similar to some being studied would

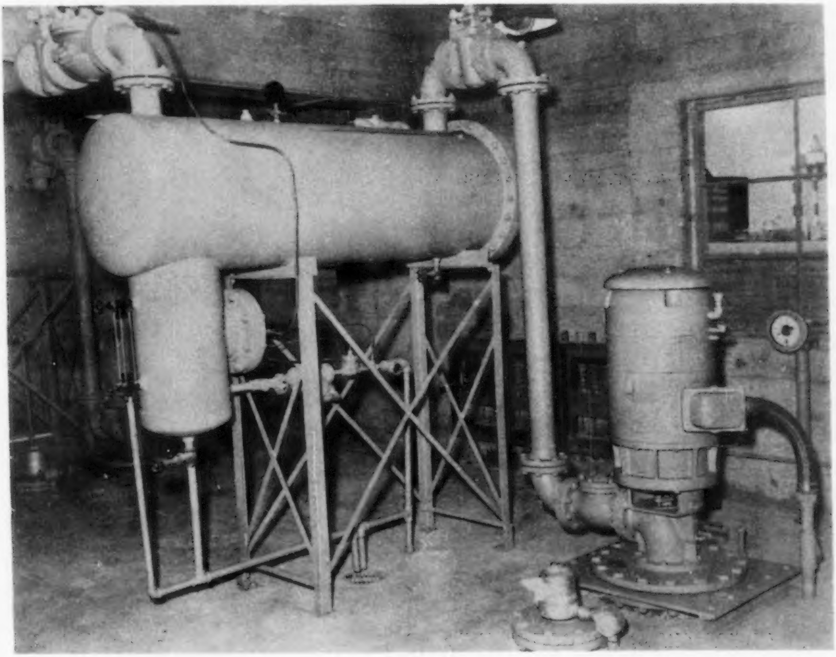

Fig. 2.

not meet the military requirements. The first fueling system capable of fueling at rates of approximately 600 GPM was designed in 1949, and installed in 1950. The basis of design required the operating storage tank to be installed underground as near the parking apron as aircraft safety would allow. The clearance distance at that time was 125 feet from the apron paving edge to pump house structure. (Fig. 2). The deep well turbine pumps in the tanks were designed to pump the fuel through water separators and piping manifold to pits 60 feet from apron edge (this distance necessary to provide clearance for propellers). In these pits were installed a micronic filter, a meter and a control valve, electrically controlled by push button switch on an 18 inch post near a pit. (Fig. 3). The fueling outlet, presently referred to as a hydrant outlet, was located just off the apron edge. At that stage of operation of the B-36 aircraft, it was thought that the aircraft would be taxied to the fueling point, filled with fuel through a hose and taxied to its normal parking position to await orders to make a flight. Defueling was not considered to be a problem prior to actual operation and was not included at each fueling point. After

Fig. 3.

the aircraft were completely fueled and allowed to stand it became apparent that a fully fueled aircraft could not be parked for an extended time. The tires took a semipermanent set, so they were lopsided and would not roll. This condition made it necessary to provide defueling capability in the fueling system. This defueling requirement greatly increased the complexity of the fueling facility.

(Fig. 4). It was necessary to provide a two pipe system from the pump house to the filter-meter pit, one for fueling and the other for defueling. Defueling was by gravity since the B-36 fuel tanks were 12 to 15 feet above the apron. (Fig. 5). The control valve had to be modified to control both fueling and defueling. The meter was relocated to provide for checking the gallons of fuel defueled as well as fueled. (Fig. 6). Another change moved the fueling outlet into the pavement—actually for B-36 aircraft it was installed on the center line of the taxiway between parking stubs. This proved very unsatisfactory since an aircraft being fueled blocked the moving of other aircraft in that area for 40 to 50 minutes. Pumping 20,000 gallons of fuel took that

Fig. 4.

length of time when spotting, connecting, disconnecting fueling hose and removing aircraft was considered.

As new aircraft were developed, designed and built it was apparent with the increase in fuel required to push them through the air that additional improvements in the fueling facilities would be necessary. Also these jet type aircraft being more complicated to start and move than propeller type indicated that fuel should be delivered into the aircraft at its parking position. This requirement necessitated another major change in the fueling system. In order to meet this requirement without obstructing the apron area with fixed above ground facilities the multiple outlet hydrant fueling system was designed and standardized.

The systems being standard for all Air Force bases world-wide must be capable of fueling any military aircraft equipped with a single point fueling system. The single point fueling method is the International Standards for Military Aircraft. The present multiple outlet system is based on a requirement for 100,000 gallons of operating storage for each 600 GPM fueling rate

Fig. 5.

with 50 psi $\pm$ 5 at the aircraft. This pressure is required to force 600 GPM through the piping of some aircraft now in use. The later bombers do not require 50 psi pressure for fuel to be delivered into their tanks. The pump houses are sited as near as possible to the apron, consistent with clearance criteria. Each pump house consists of 2, 3 or 4 hydrant systems which is what we call the 100,000 gallon, 600 GPM unit. (Fig. 7).

The schematic layout shows a typical 3 hydrant systems. The pump house consists of six 50,000 gallon tanks installed underground with a 300 GPM deep well turbine pump installed in each. The tanks are approximately 10' -6" in diameter by 70 ft. long in groups of 3 end to end so the pumps can be inclosed in a building. Each tank has 2 manholes for safety in cleaning, a liquid level gauge, a stick gauge pipe, a clean-out pipe, a high level shut-off valve and a low level shut-off switch to stop the pump. Adjacent to each pump is a 300 GPM filter-water separator. These have been a source of many problems. The first units were designed to handle aviation gasoline and functioned satisfactorily. Then there was introduced the requirement to

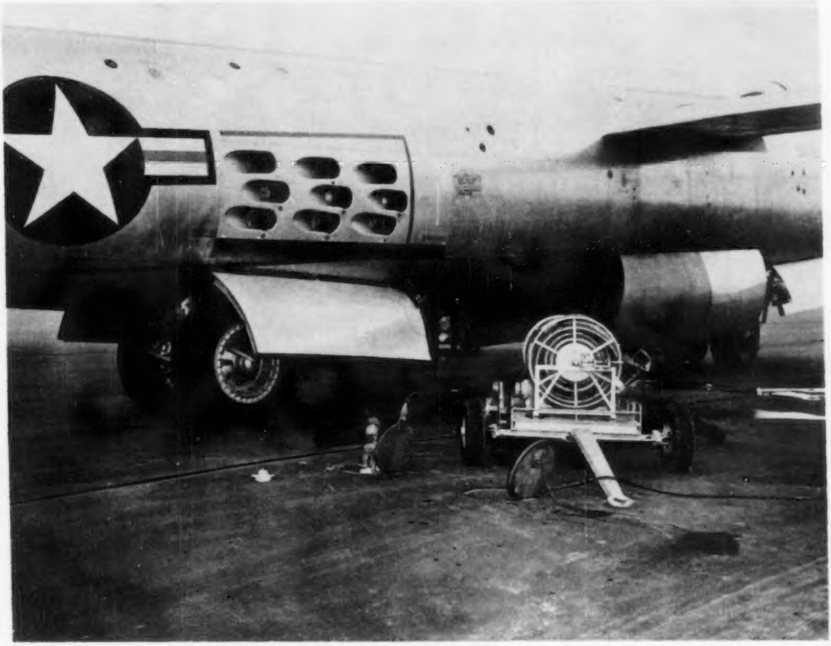

Fig. 6.

handle jet fuel and the water was not all removed and thus the Air Force asked the suppliers to improve the design to provide water-free jet fuel. It is only within the last year that satisfactory items became available.

The pump house piping was changed to provide for installation near the floor rather than being hung from the roof. (Fig. 8). This provides easy access to valves and keeps the piping free from the building structure. By using this type of installation the building roof and walls could be blown away with only minor disturbance of the piping, a desirable operational feature in the event of an external explosion. The fuel flows through proper sized pipe to keep the velocity below 7 ft. per second from the pump house out to the control pit located 60 feet from the heavy paving edge. (Fig. 9). This pit contains a flow control valve and self-priming centrifugal defueling pump both are electrically controlled by push button switches at the various fueling outlets. The filter and meter were removed and installed on a cart. The valve controls the fuel flow from fueling to defueling or no flow as desired by the operator at the fueling outlet. (Fig. 10). The defueling pump has a

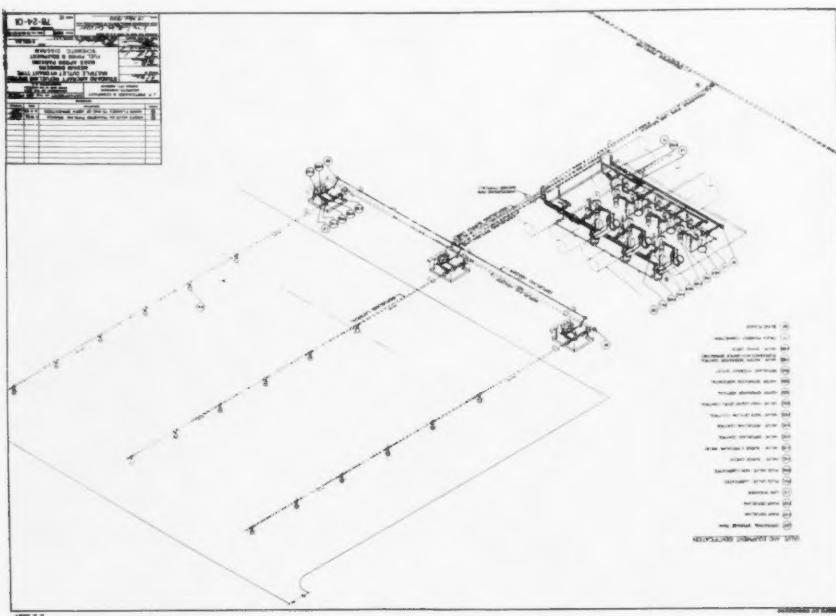

Fig. 7.

vacuum control as well as the two speed controls at the fueling outlet, that will stop the pump when a specific vacuum is developed by valve closure at the fueling outlet. The present allowable vacuum is 19 inches of mercury, which actual field tests indicated would give satisfactory operation. The defueling pump operates at 200 GPM when removing fuel from aircraft and pumping it back into the underground operating storage tanks. For reduced flows such as draining hose and filter or emptying only one small tank in the aircraft the pump operates at 50 GPM. There are two pipe runs from the pump house to the control pit, one for fueling and the other for defueling. From the pit out under the pavement to the multiple outlets there is only one pipe run. Both fueling and defueling are accomplished through this pipe so it is only possible to fuel or defuel at any specific time. This was considered a satisfactory condition since it is always necessary to defuel the hose and filter on the cart after each fueling operation. With the capability of only deliverying 600 GPM per lateral that has several fueling outlets there is no

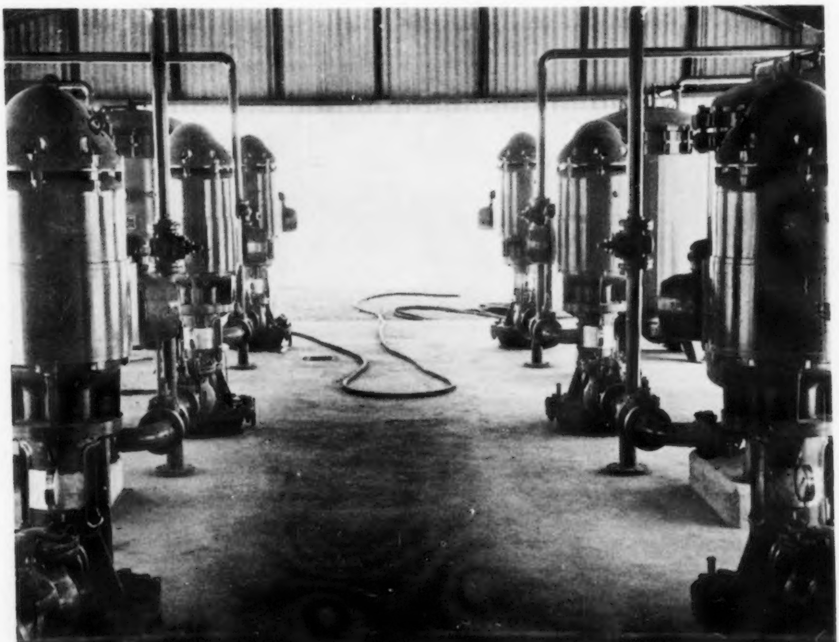

Fig. 8.

time to be gained by trying to fuel from more than one outlet. The advantage of the multiple outlet concept is that the aircraft do not require moving to be fueled. In order to reduce the chances of confusing the fueling and defueling operation we have provided two plug-in cable type control switches. (Fig. 11). The switches are on short 6 foot rubber covered cables that are stored on the filter-meter hose cart, each cable has a different type plug so it can only be inserted in the proper socket. The sockets are installed in the casting set in the concrete paving. Each plug receptable has a spring loaded cover to retard the entrance of dirt and water. Between these sockets there is an emergency stop switch. Grooves are provided in the concrete to drain the water away from the casting. The fueling switch has only an "ON" button for 600 GPM and an "OFF" button, while the defueling switch has an extra slow speed circuit. The regular defueling switch provides for pumping at 200 GPM while the slow switch is for pumping only 50 GPM. The type of switches has been the source of considerable investigation. The dead-man type was not accepted

Fig. 9.

due to the excessive time required to complete the fueling of one aircraft. Recent reports from the field reveal that dead-man type switches are being listed as deficient due to the inability of operating personnel to maintain sufficient pressure on the switch to keep the pumps running. This verifies the decision not to require dead-man type switches. The standard push button type holding switch has been required. This eliminates the surges that would be caused by the alternate starting and stopping of the pumps when pressure was relieved on the dead-man type switch. (Fig. 12). A special fuel level control valve is installed just below the coupler valve, designed to close when air or vapor passes the coupler valve. This closure creates the vacuum that stops the defueling pump. This condition was established due to the requirement of not wanting any air to enter the piping system. The hydrant coupler valve and fuel level control valve are new items that were developed by equipment suppliers. These items were necessary to meet the defueling requirements due to the necessity of emptying the hose and a portion of the micronic filter to reduce the weight of the cart. These items have

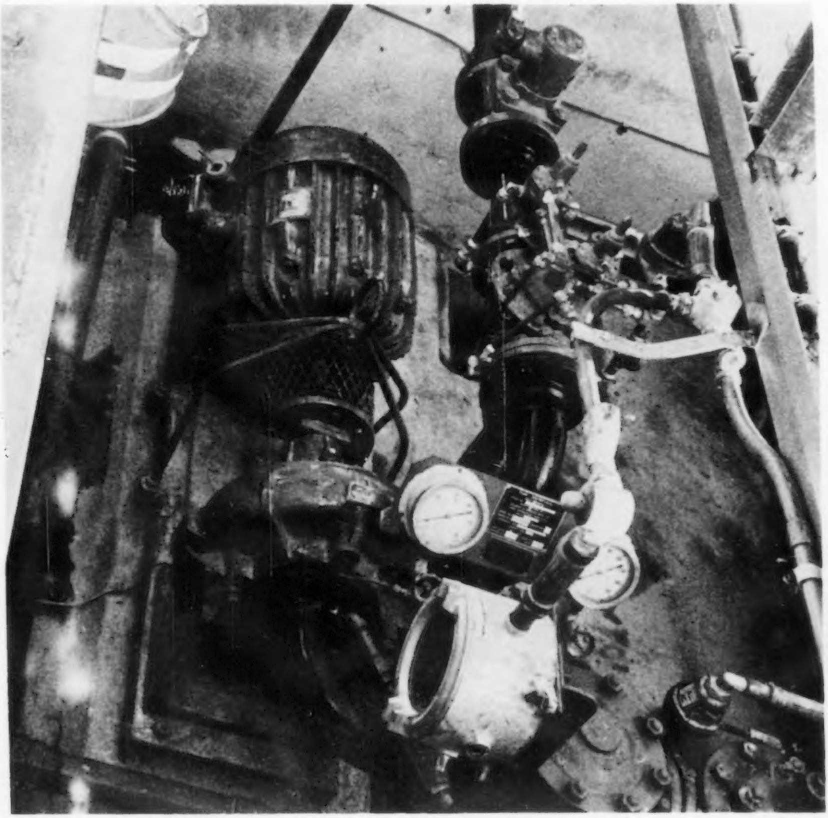

Fig. 10.

been under development for two years and still require improvements. (Fig. 13). The present coupler valve is loo large and unweildly when connected to the hose for easy, rapid connection to the installed portion in the pit. A smaller item is being tested at this time that appears to be a more suitable unit. The fuel level control valve has caused many irrating delays in the defueling operations. Improvements are being developed and tested to reduce the chances for improper operation. These items have been discussed to bring out the problems in connection with designing a new fueling system requiring items of equipment not presently available. There will always be excessive delay in obtaining suitable equipment.

It was decided that the fuel must be filtered and metered just before entering the aircraft. To meet this requirement it was necessary to have a filter-meter hose cart that would be relatively small and lightweight to allow for moving by manpower. (Fig. 14). This item was researched, developed, designed and built for the Air Force by a commercial company. It consists of a

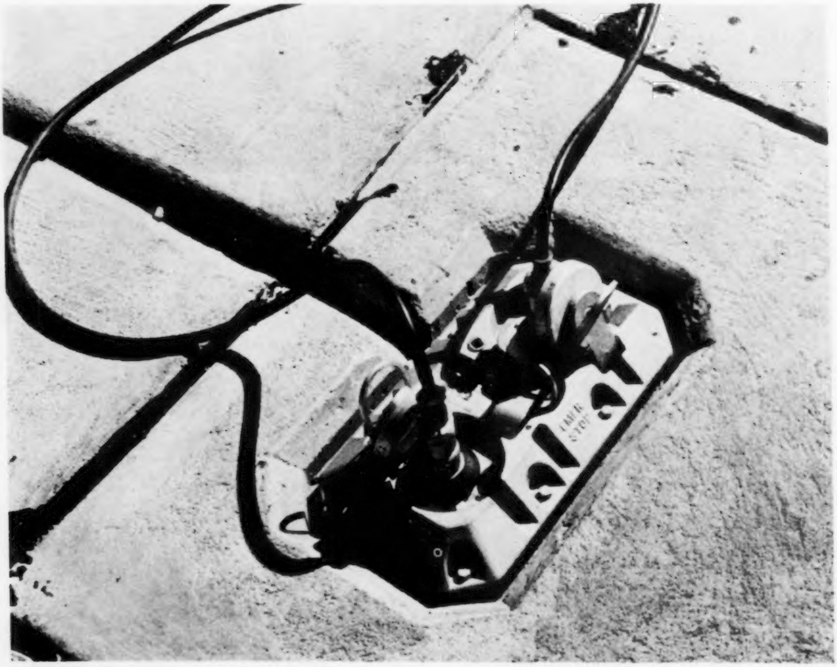

Fig. 11.

four wheel cart with a total of 50 feet of 4-inch hose; 15 feet on the inlet end and 35 feet on the discharge end. (Fig. 15). The flow enters through a high pressure control valve then goes to the 600 GPM micronic filter and out through the 600 GPM meter and two surge suppressor. The development of this cart was started in the Spring of 1954 and the production items were not delivered to air bases until January 1957, a lead time of about two and one-half years. This again brings out the fact that new equipment when required to be developed from an idea takes time. Many items are not ready for use before the need is gone due to new operational requirements. As the new aircraft are operated, procedures that appeared good in the planning are not the best so new equipment is required to provide for the better method of operation. (Fig. 16). This is the connection for the hose at the aircraft.

Changes in jet aircraft are creating additional fueling problems. It may be necessary to modify the present multiple outlet design to meet special conditions. Due to our almost continuous change in operating personnel it is

Fig. 12.

necessary to include many special features to deter improper operation. Within the last year a study was made regarding possible improvements that would make the fueling system more suitable to meet the ever-changing aircraft design. One suggestion has been to bring back the old pressure system idea that was found unsuitable in 1947. A very weak point in the pressure system is that it would continue to pump fuel, if a leak occurred, until fuel appeared above the ground at some easy-to-notice point. Due to the type of operators we must use, this is a serious problem. This may sound impossible to many but I have talked to the operators (youngsters usually) on many air bases, their answer, when I inquire about how the pumps start when fuel is required, is, "I have no trouble, I just turn them on when I come on shift, and stop them when I go off duty." So you can see that a pump starting up when there is no aircraft to be fueled would not be noticed as a leak. Experience with the commercial pressure system at Ft. Worth, Texas, showed considerable delay in locating a leak. This personnel problem is not always the

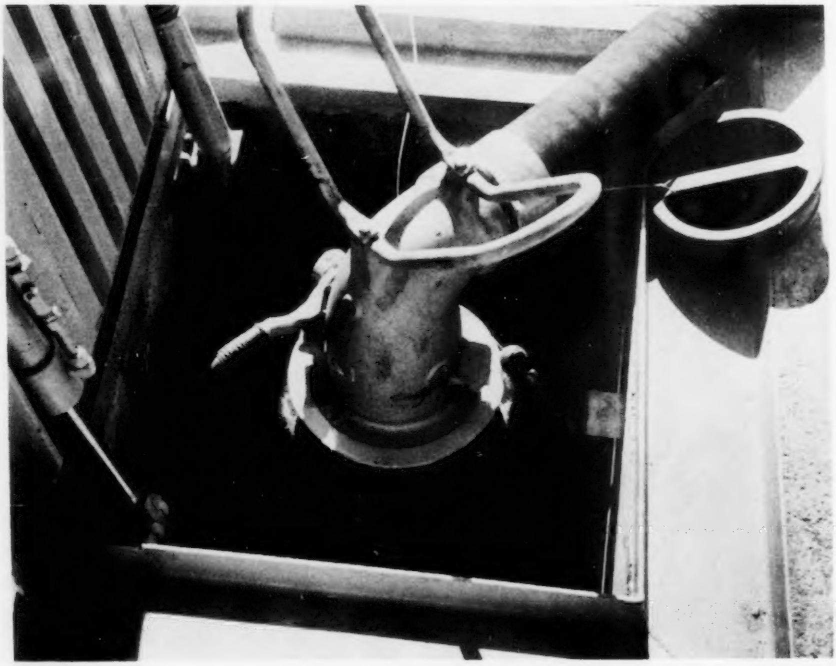

Fig. 13.

case, we do have many men that take an interest in fueling and do wonderful jobs. The thrill of being fueling control man on an aircraft tanker is an interesting assignment for the boys to anticipate. The men enjoy such work and develop good relationship which assists in making a tough job easy. To show how this works I will tell you about an incident during the non-stop around the world flight of the B-52 bombers. This flight required several refuelings in the air, a very nerve-racking operation. The faster jet must fly to the rear of a tanker aircraft and allow the pipe (boom) from the tanker to be inserted in the fueling inlet in the nose of the bomber. The pilot of a bomber was rather tense as he started the approach to the tanker but he got into the proper position so the fueling boom could be extended and make a connection. As the boom approached he noticed a green and white sign on the stabilizers which read, "We give S & H green stamps." This relaxed everyone and the whole operation was very successful, as reported by the newspapers.

Fig. 14.

When you have an apron 5,000 ft. long x 1,100 ft. wide covered with aircraft parked at 136 ft. x 293 ft. spacing, it is impossible to observe which aircraft of several are actually being fueled. This condition is common on our existing medium bomber bases. The latest trend is toward parking jet aircraft near the apron edge tail out to reduce blast effect on other aircraft on the apron. If this parking procedure is adopted we may have to go to a modification of our old design with fueling outlet near the edge of the apron. (Fig. 17). This design is for heavy bombers and provides only two fueling outlets for each 100,000 gallon storage and 600 GPM pumping capability. The pump houses are sited on both sides of the apron, with fueling outlets in the pavement along each side. Each lateral has a control pit and defueling pump. This design reduces the length of pipe from the pump house, a desirable feature, since the long lines are causing trouble in our existing systems by increasing the surge build-up at shut-off. Another problem is with the

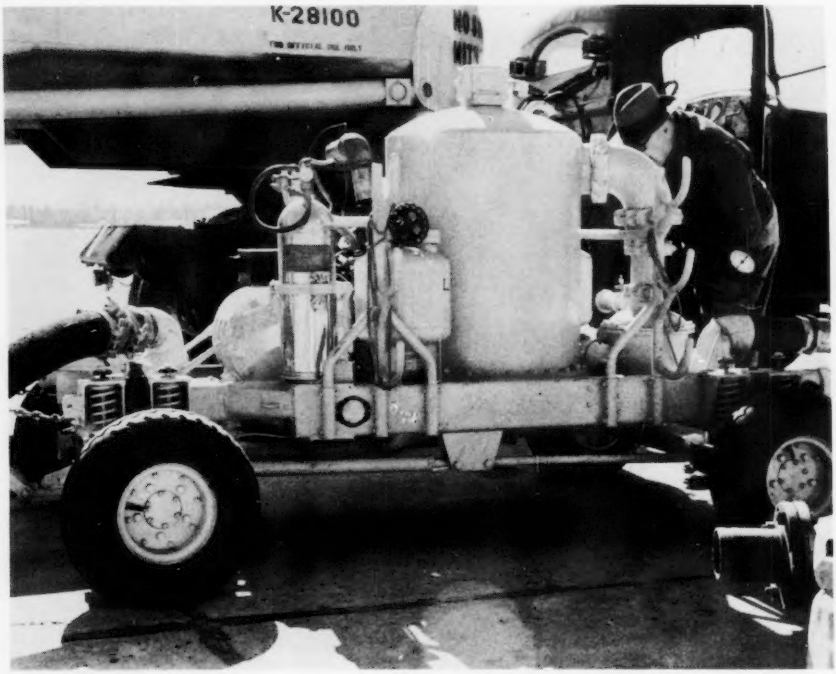

Fig. 15.

defueling pumps having to pump through these long lines back to operating storage. We are getting reports of poor operation on a few of our systems that were designed with excessive long lines. These problems are still in the future but may be forced upon us shortly. There is also the problem that future aircraft will require more fuel. Our present requirement provides for two heavy bombers for each hydrant system so it may be necessary to change this to meet fueling time requirements for larger aircraft. It is possible to cut the overall fueling time for a squadron of aircraft in half by doubling the number of 600 GPM systems on a base. This is without increasing the actual fueling capability of the basic system. A requirement greater than this will require an increase in flow rate with the numerous problems in equipment that will come along with such a change.

Fig. 16.

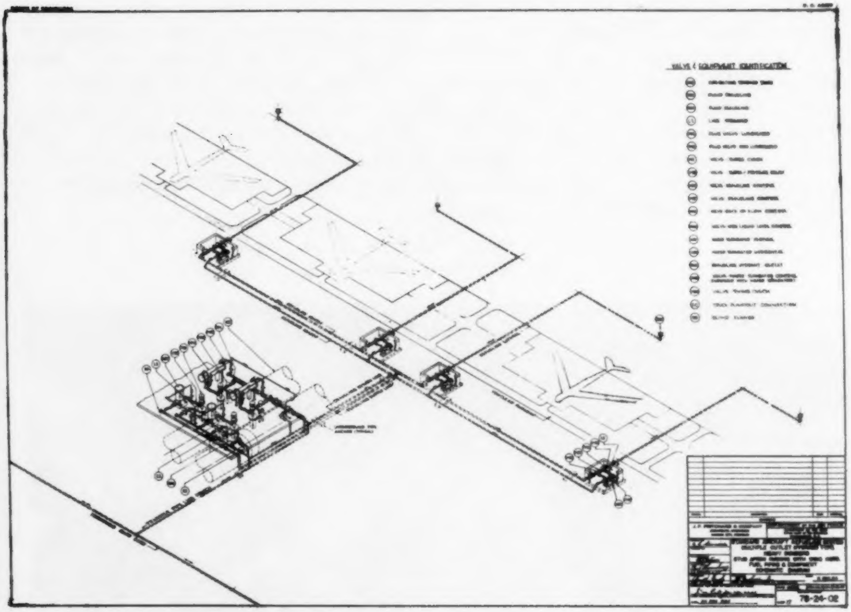

Fig. 17.

CONCLUSIONS

The Air Force recognizes that effective maintenance is as important as the design and construction of the facilities. Accordingly, incorporated into the plans are design features which will result in reduced maintenance problems, even though the initial construction cost may be slightly higher. Considering the long term operation of these facilities, this practice is well worth while. The multiple outlet systems are just being put into regular operation now that the filter-meter hose carts are available and informal reports indicate very satisfactory operation. Fueling time is greatly reduced. The fueling system will receive more favorable comments as operators become acquainted with the time saving features.

Paper 1483 December, 1957 AT 2

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

AIRPORT MASTER PLANNING FOR THE JET AGE[a]

Herbert H. Howell,[1] M. ASCE
(Proc. Paper 1483)

ABSTRACT

America, prosperous and growing, spends huge amounts of money for transportation annually, particularly air transportation. Continuous increases in air traffic are forecast resulting in greater loads on our airports system, developed through local initiative. Communities must plan for the future on a system concept because of the interdependence of all airports in the system.

The writer is going to avoid, insofar as possible, any discussion of detailed planning of individual airports. Rather, there will be presented the subject of system planning and a discussion of the foreseeable requirements of a national system of airports. In general, a series of illustrations will be used to indicate some of the bases for CAA forecasting, to show some of these forecasts and to indicate the need for airport system planning.

First of all, what are we planning for: The answer is more—more people, spending more money, going more places in more aircraft.

As Figure 1 shows, we are a prosperous nation. Since 1946 our economy has been in a state of vigorous expansion. Perhaps the best measure of the total market value of national output is the gross national product, shown by the upper line, which reached 387 billion dollars in 1955. Projections indicate a potential gross national product of approximately $550 billion by 1965, and $650 billion by 1970. The lower line shows the per capita gross national

Note: Discussion open until May 1, 1958. Paper 1483 is part of the copyrighted Journal of the Air Transport Division of the American Society of Civil Engineers, Vol. 83, No. AT 2, December, 1957.

a. Paper prepared for presentation at Jet Age Airport Conference, New York, N. Y., May, 1957.

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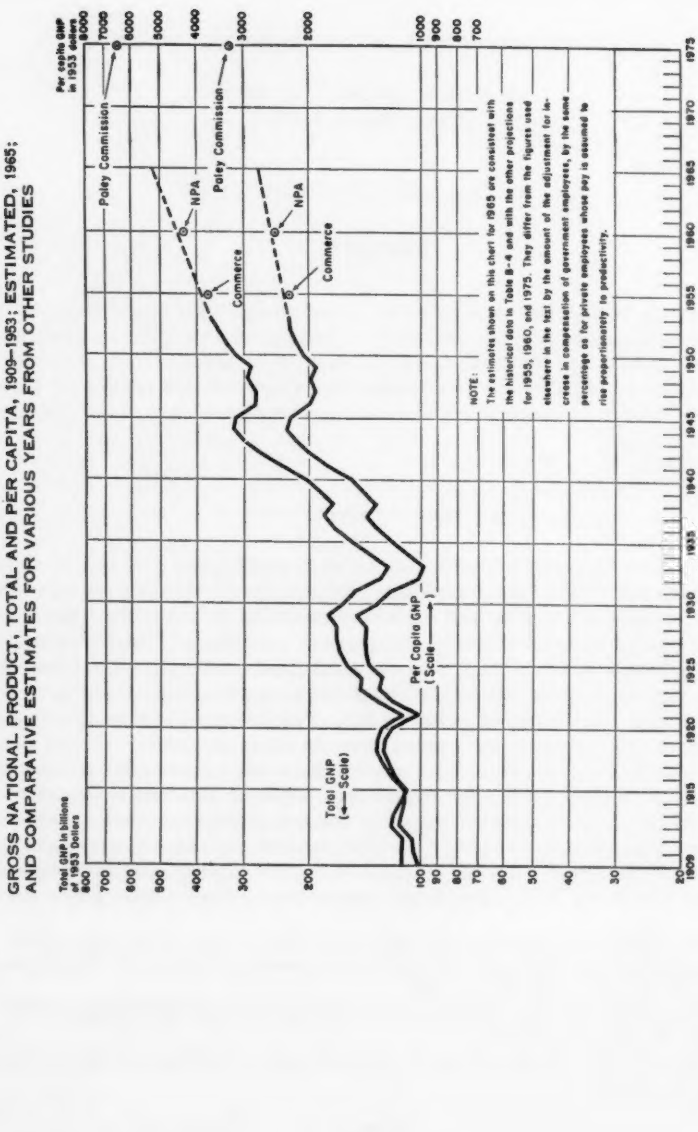
GROSS NATIONAL PRODUCT, TOTAL AND PER CAPITA, 1909–1953; ESTIMATED, 1965; AND COMPARATIVE ESTIMATES FOR VARIOUS YEARS FROM OTHER STUDIES
Total GNP in billions of 1953 Dollars
Per capita GNP in 1953 dollars
Total GNP (← Scale)
Per Capita GNP (Scale →)
Paley Commission
NPA
Commerce
NOTE: The estimates shown on this chart for 1965 are consistent with the historical data in Table B-4 and with the other projections for 1955, 1960, and 1975. They differ from the figures used elsewhere in the text by the amount of the adjustment for increase in compensation of government employees, by the same percentage as for private employees whose pay is assumed to rise proportionately to productivity.
1909
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975

Fig. 1

product and that, too, will increase. There seems little doubt that the tremendous expansion in output which these figures signify will create an extremely favorable environment for further growth in air transportation.

As Figure 2 shows, we are a growing nation. Our population is increasing at the rate of nearly three million people a year—just about as many people as live in the San Francisco-Oakland metropolitan area. The Bureau of the Census estimates that population growth will continue at a rapid rate, and that the population of the United States should total approximately 210 million by 1970. During the next fifteen years, more than 44 million additional persons will have to be supplied with food, clothing, housing, and other necessities of life, including transportation.

Figure 3 shows the location of the metropolitan areas which have been so designated by the Bureau of the Census. Over 98% of the increase in U. S. civilian population between 1950 and 1955 took place in these 168 standard metropolitan areas. Virtually all of our population increase is occurring in urban areas, with a decline in rural population. It is expected that population in the Far West and the Southwest will grow more rapidly than the average, which should provide particular stimulus to air traffic between these points and the more established population centers in the East and Midwest.

As Figure 4 shows, we are spending more money each year on travel. The top line shows total personal consumption expenditures during the period 1946 to 1955. Expenditures for transportation went up from $12 billion in 1946 to $32 billion in 1955, as shown by the bottom line. The percentage of personal consumption expenditures for transportation, shown by the middle line, went up from 8% in 1946 to 13% in 1955. Consumer spending for air travel has grown at a considerably more rapid pace. Economic figures reveal that consumption expenditures for airline travel have increased more rapidly during the postwar period than for any other major product or service category.

Figure 5 shows that we are traveling more, and that the percentage of common carrier travel that is carried by the scheduled air carriers is increasing. The top line shows all intercity travel, and the line below it shows travel by private automobile. The bulk of our total intercity travel is by automobile, amounting to about 85%. The third line shows the total common carrier travel, followed by railways, motor carriers, scheduled air carriers, and air coach service. The scheduled air carrier percentage of common carrier passengers is increasing. In 1949, 11% of common carrier passenger miles represented the scheduled air carrier share, while in 1955, this percentage had risen to 33%. It is expected that either in 1957 or 1958 the air carrier traffic will exceed that carried by the railroads. The dotted line shows the forecast trend for air carrier passenger miles.

As Figure 6 shows, not all air traffic is handled by the scheduled air carriers. Fig. 6 shows the total hours flown in 1955 by U. S. air carriers, in the lower bar, as compared to hours flown by general aviation aircraft, in the upper bar. It is perhaps surprising to note that general aviation accounts for approximately 70% of the total aircraft hours, with business transportation actually accounting for more hours in the air than do the scheduled air carrier aircraft. Business transportation has grown rapidly to the point that it is the healthiest segment of non air-carrier flying.

Figure 7 shows air traffic hubs within the United States. Just as population is becoming concentrated in metropolitan areas, so is air traffic concentrated in our hubs. We define as air traffic hubs those communities which

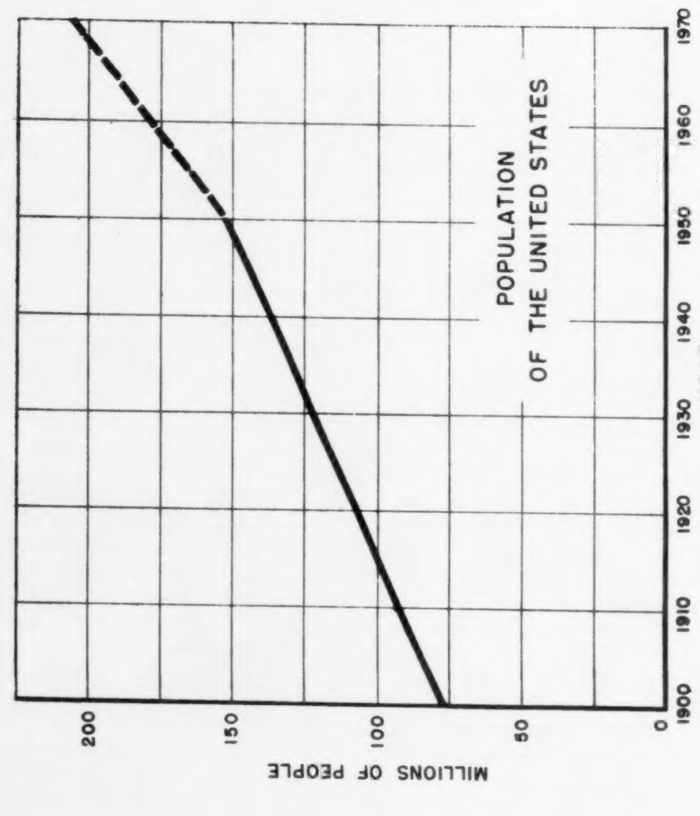
POPULATION
OF THE UNITED STATES
YEAR
MILLIONS OF PEOPLE
1900
1910
1920
1930
1940
1950
1960
1970
0
50
100
150
200

Fig. 2

Figure 2.—STANDARD METROPOLITAN AREAS OF THE UNITED STATES: 1950

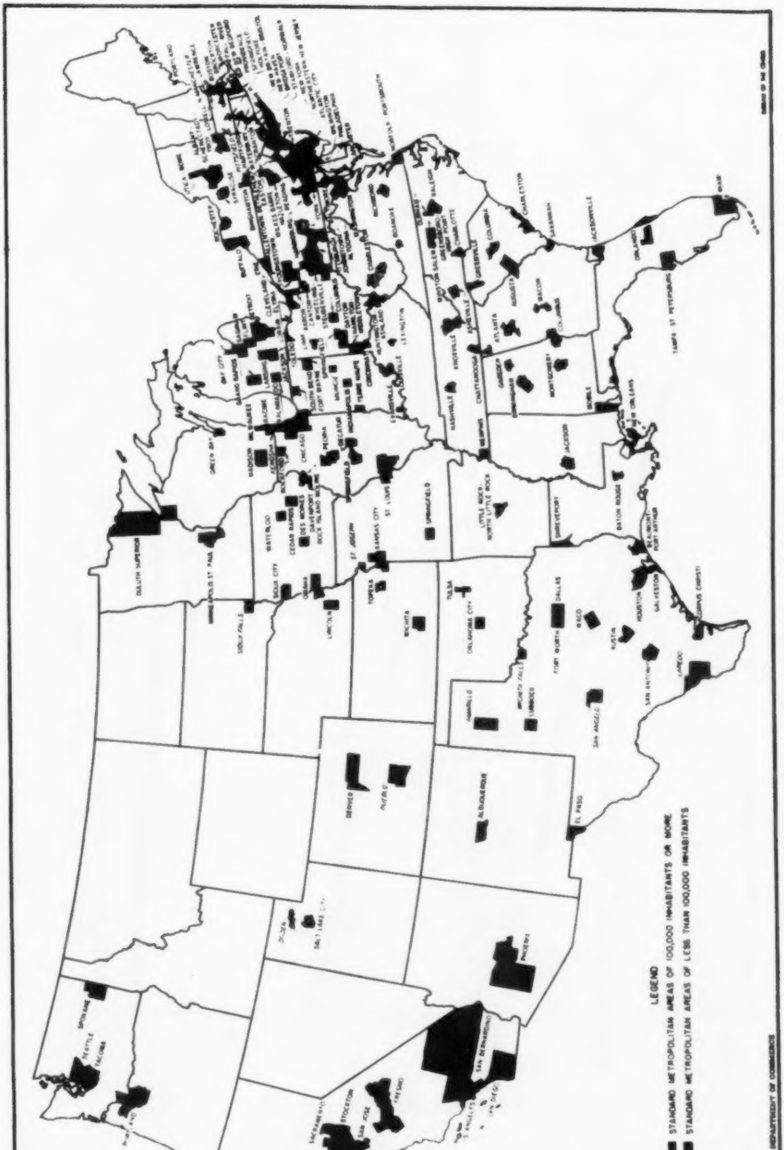

Fig. 3

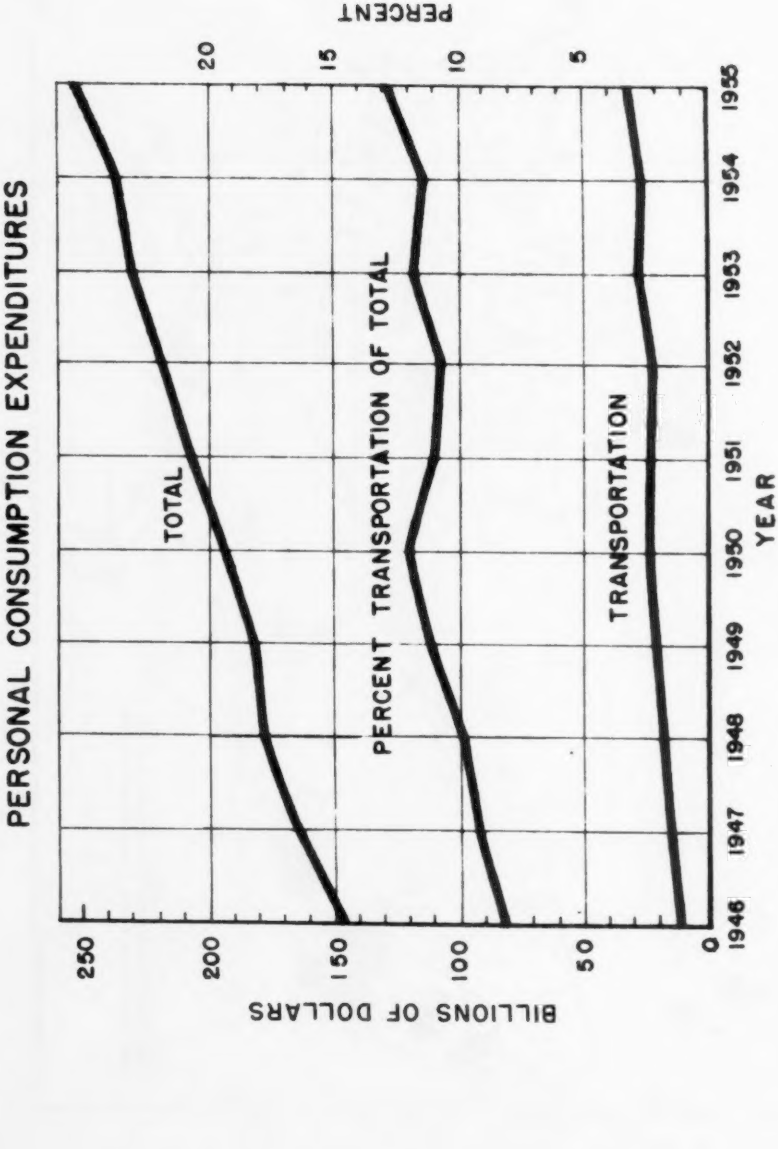
PERSONAL CONSUMPTION EXPENDITURES
TOTAL
PERCENT TRANSPORTATION OF TOTAL
TRANSPORTATION
BILLIONS OF DOLLARS
PERCENT
YEAR
250
200
150
100
50
0
20
15
10
5
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955

Fig. 4

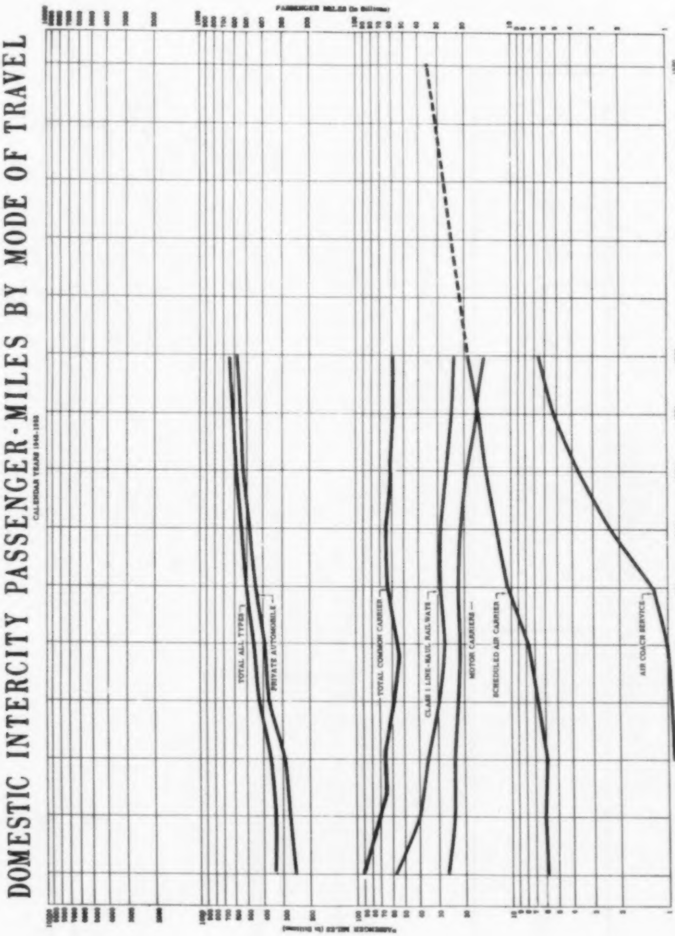
DOMESTIC INTERCITY PASSENGER-MILES BY MODE OF TRAVEL
TOTAL ALL TYPES
PRIVATE AUTOMOBILE
TOTAL COMMON CARRIER
CLASS I LINE-HAUL RAILWAYS
MOTOR CARRIERS
SCHEDULED AIR CARRIER
AIR COACH SERVICE

Fig. 5

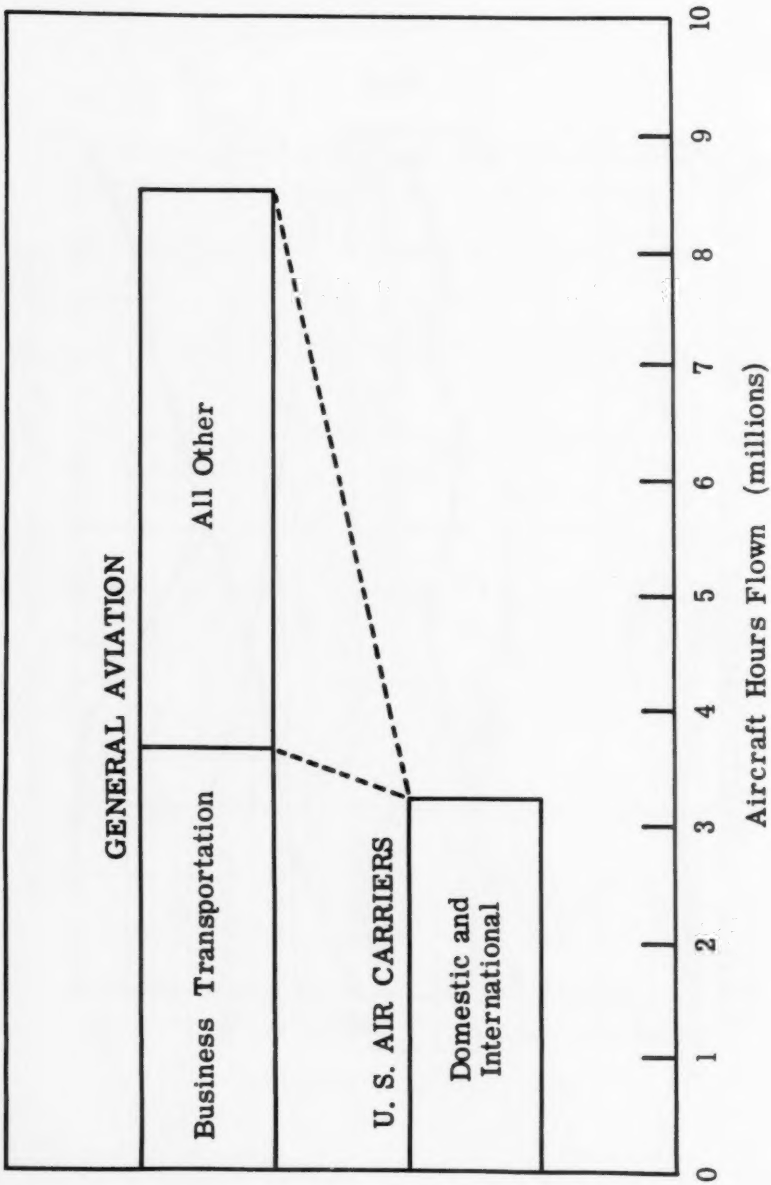
GENERAL AVIATION
Business Transportation
All Other
U. S. AIR CARRIERS
Domestic and International
0
1
2
3
4
5
6
7
8
9
10
Aircraft Hours Flown (millions)

Fig. 6

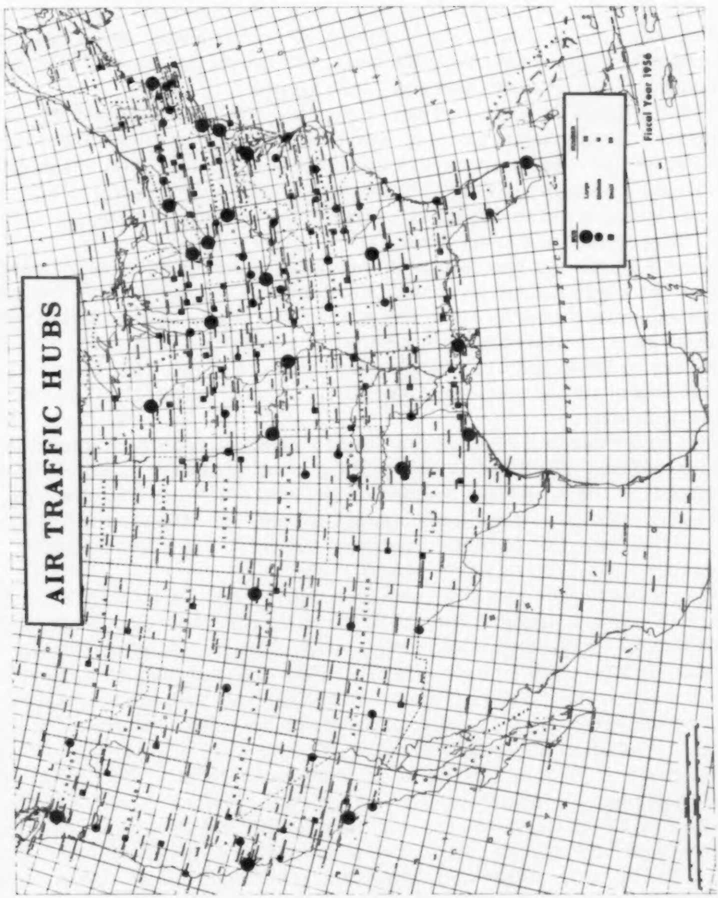

Fig. 7

enplane substantial percentages of domestic airline passengers. There are twenty-two communities which are classed as large hubs, each of which enplanes more than 1% of the nation's air carrier passengers. There are forty-one medium hubs, and ninety-six small hubs. The remainder of the 550 communities served by scheduled carriers are rated as non hubs, since no one of them generates a substantial volume of airline traffic.

Figure 8 further bears out the fact that traffic is concentrated at hub communities. We use enplaned passengers as the index to determine hubs, but generally all other aeronautical activity falls into the same pattern as indicated by this simple index. Fig. 8 shows the communities with significant instrument weather traffic between them, and invariably such traffic flows between the large, medium and small hub airports.

To recapitulate, this first group of charts shows that our economy is expanding, our population is growing, and that aviation activity is increasing. An increasing percent of income is being spent on transportation and aviation accounts for a larger share of transportation each year. Aviation's growth, just as the population increase, is concentrated in metropolitan and urban areas. Now let us look to the future.

Figure 9 shows our forecast of domestic air carrier revenue passengers, based on the current CAA forecast. Air carrier passengers have trebled in the postwar period 1947 to 1955, and a further trebling is anticipated by 1970. As can be seen, the forecast is for 66 million passengers in 1960, 93 million passengers in 1965, and 118 million passengers in 1970. This is our basic forecast, since airline passengers serve as a basic index for all phases of aeronautical activity.

As Figure 10 shows, the increase in aeronautical activity is generally going to be uniform. This shows the forecast of business flying which, as has been stated, is the healthiest segment of general aviation. The previous forecast was for numbers of airline passengers, whereas this forecast deals with total hours flown. The forecast represents about 2-1/2 times as much business flying in 1970 as there was in 1955.

Figure 11 indicates just how busy America's airports actually are. The middle bar shows activity at the 185 airports at which the CAA maintains control towers. (These airports have a median traffic of approximately 100,000 aircraft movements per year.) This compares very favorably with the traffic at Air Force Bases, shown in the top bar, with median activity of 45,000 movements; and with Navy airports, shown in the lower bar, which also had a median of 45,000 movements. Traffic at U. S. civil airports is significantly heavier than the traffic at European airports. These 19 European airports had a median activity of 37,000 movements.

As Figure 12 shows, however, busy as our airports are, they are going to be even busier. Traffic in 1955 at 185 airports with CAA towers aggregated about 13 million air carrier and itinerant aircraft operations. We forecast that this will increase about 2-1/2 times in the next fifteen years.

Figure 13 shows that as traffic increases, the percentage increase of instrument operation will far exceed the over-all growth percentages. More air space is going to be under control and more aircraft with better electronic equipment will fly under inclement weather conditions. We estimate that in the next fifteen years there will be a five-fold increase in the 600,000 instrument approaches made in 1955. The forecast is for 3.3 million instrument approaches in 1970.

This is a very brief summary of our over-all forecast but does indicate

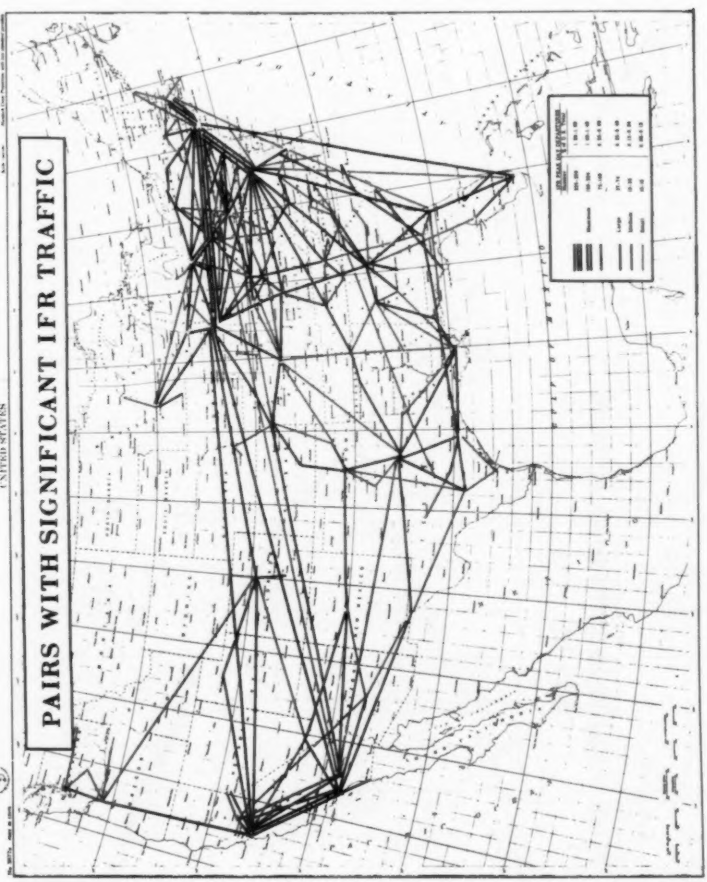

Fig. 8

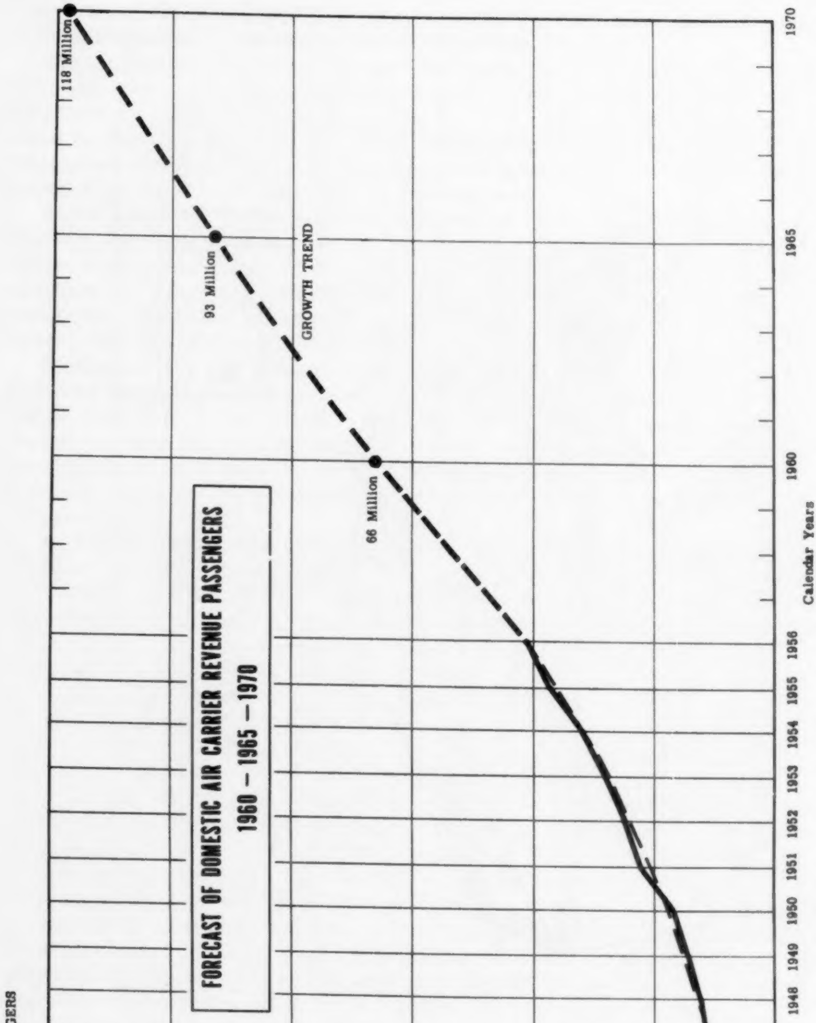
FORECAST OF DOMESTIC AIR CARRIER REVENUE PASSENGERS
1960 – 1965 – 1970
REVENUE PASSENGERS
(Millions)
118 Million
93 Million
66 Million
GROWTH TREND
Calendar Years
120
100
80
60
40
20
0
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1960
1965
1970

Fig. 9

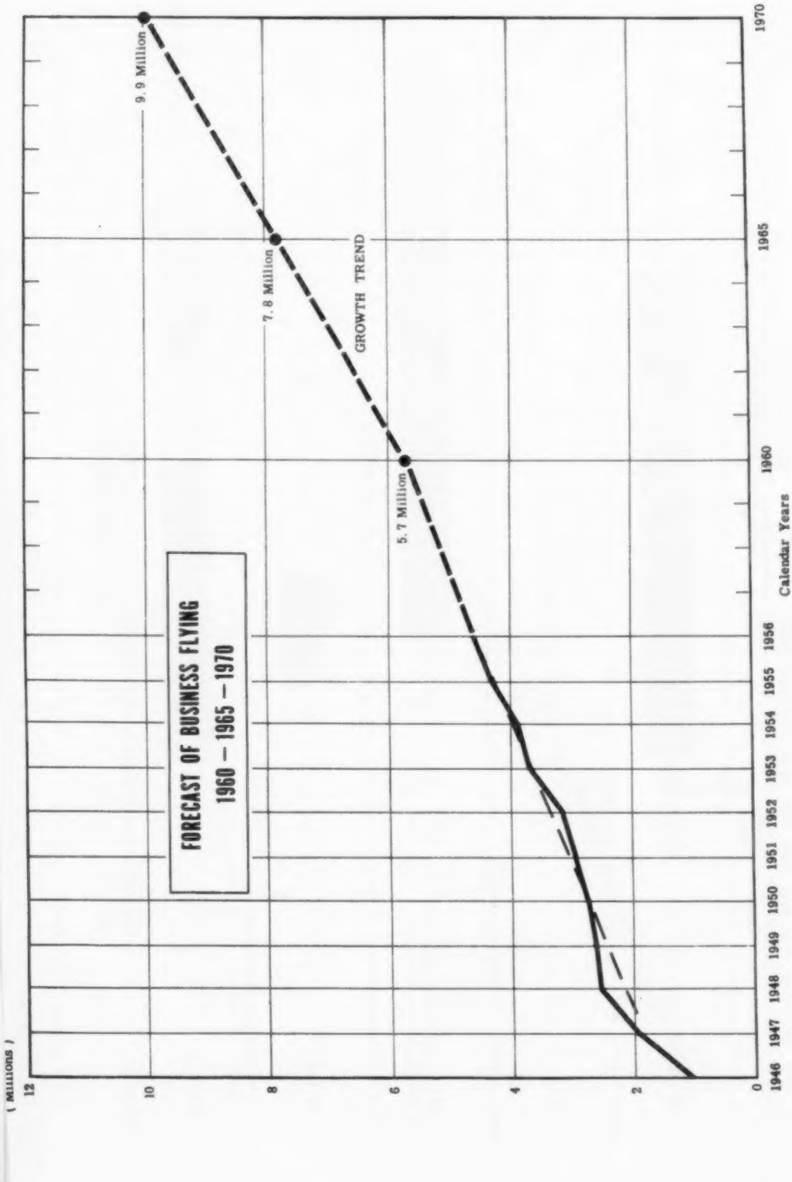
FORECAST OF BUSINESS FLYING
1960 — 1965 — 1970
9.9 Million
7.8 Million
5.7 Million
GROWTH TREND
(Millions)
12
10
8
6
4
2
0
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1960
1965
1970
Calendar Years

Fig. 10

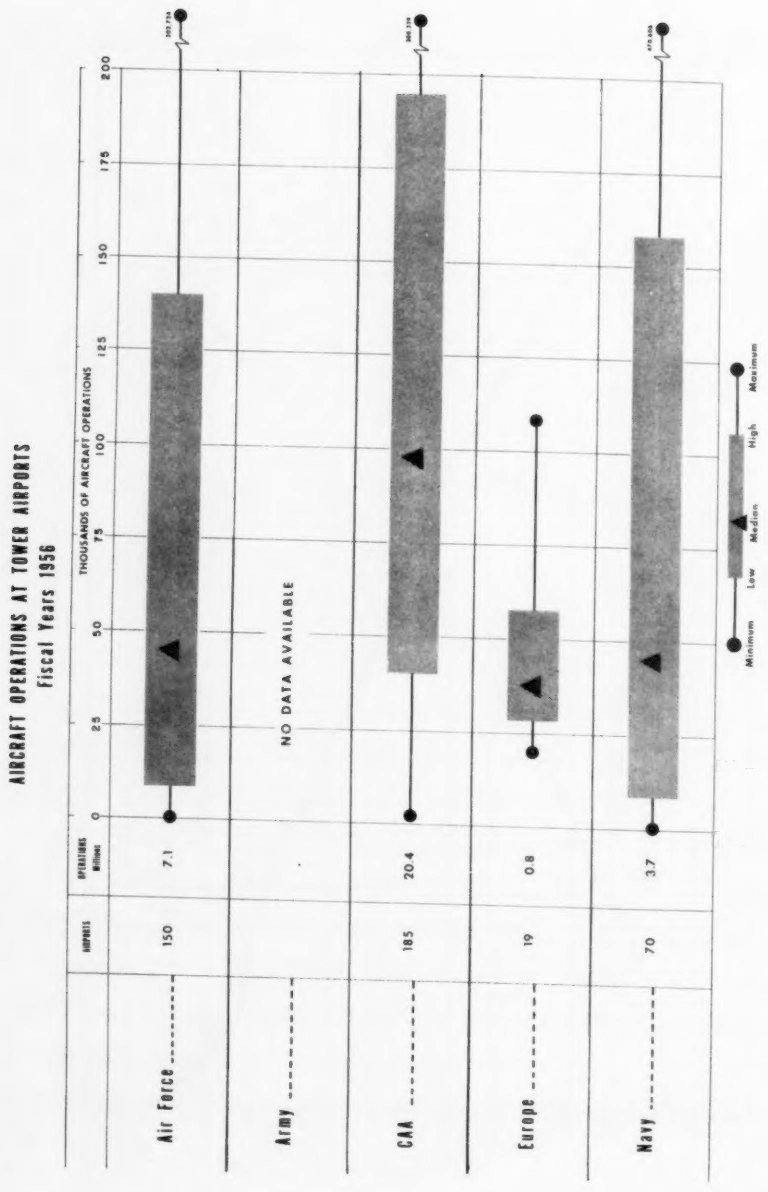
AIRCRAFT OPERATIONS AT TOWER AIRPORTS
Fiscal Years 1956
THOUSANDS OF AIRCRAFT OPERATIONS
0
25
50
75
100
125
150
175
200
AIRPORTS
OPERATIONS Millions
Air Force
150
7.1
Army
NO DATA AVAILABLE
CAA
185
20.4
Europe
19
0.8
Navy
70
3.7
Minimum
Low
Median
High
Maximum

Fig. 11

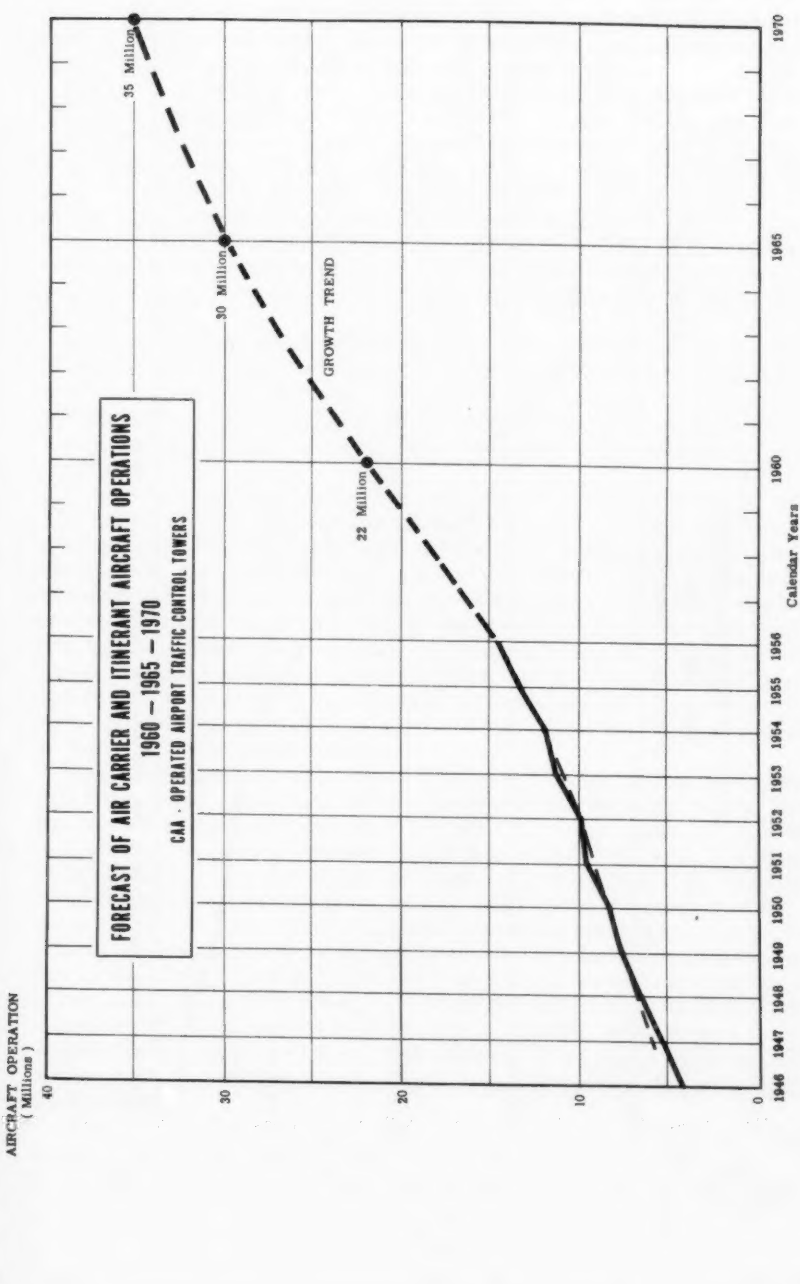
FORECAST OF AIR CARRIER AND ITINERANT AIRCRAFT OPERATIONS
1960 — 1965 — 1970
CAA - OPERATED AIRPORT TRAFFIC CONTROL TOWERS
GROWTH TREND
35 Million
30 Million
22 Million
AIRCRAFT OPERATION
(Millions)
40
30
20
10
0
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1960
1965
1970
Calendar Years

Fig. 12

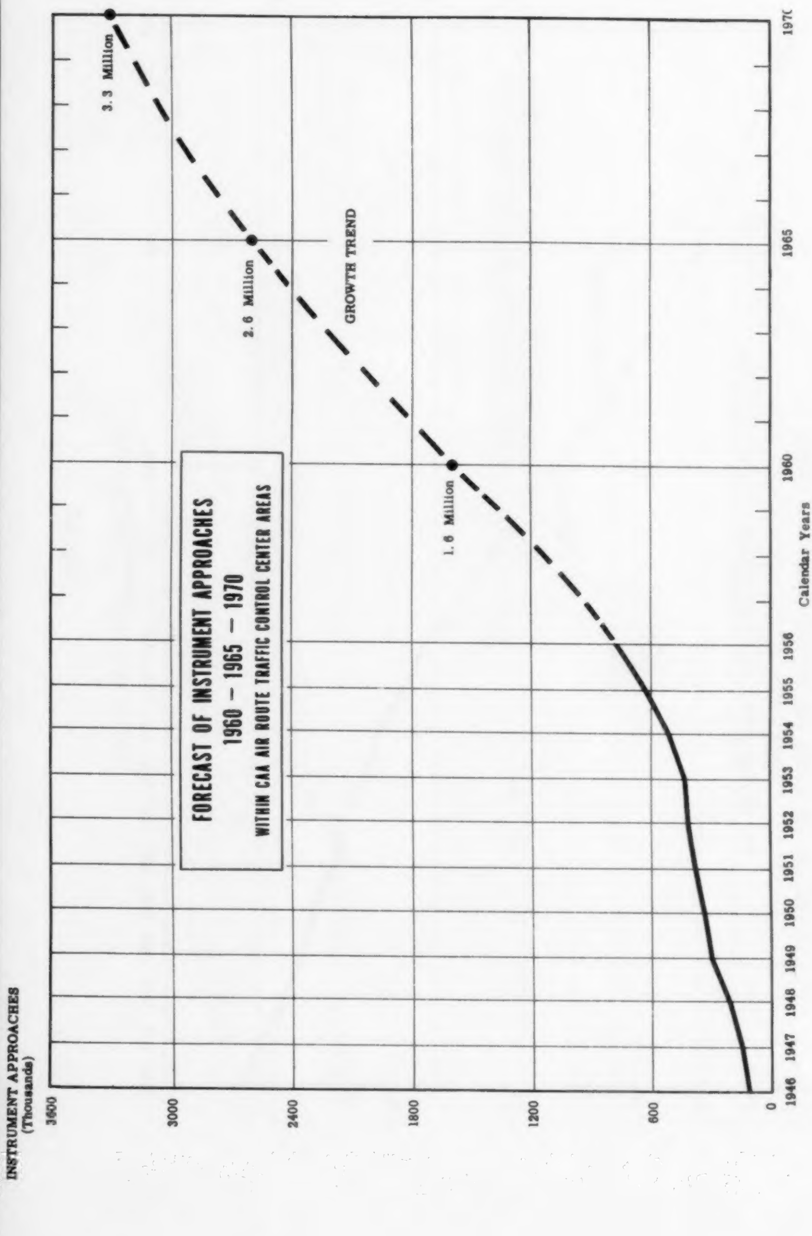
FORECAST OF INSTRUMENT APPROACHES
1960 — 1965 — 1970
WITHIN CAA AIR ROUTE TRAFFIC CONTROL CENTER AREAS
GROWTH TREND
3.3 Million
2.6 Million
1.6 Million
INSTRUMENT APPROACHES
(Thousands)
3600
3000
2400
1800
1200
600
0
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1960
1965
1970
Calendar Years

Fig. 13

that the postwar growth of civil aviation has not been a boom, but rather a steady growth that is going to continue virtually without abatement, for the foreseeable future. As this growth continues, an ever greater load is going to be imposed on our airport system and each of the airports that forms a portion of that system. A study of airport activity indicates the need for planning on a national basis. The interdependence of all airports in the national system can be shown by this next series of charts.

Figure 14 shows, for 1955, where more than 9,000,000 domestic airline passengers using New York's airports came from and went to. The size of the circle indicates the volume of passengers exchanged. New York exchanged passengers with all parts of the country—nearly 800,000 with Chicago; over 700,000 with Boston; over 600,000 with Washington; nearly half a million with Miami; and more than 300,000 with Los Angeles, Altogether there was traffic between New York and 442 communities. New Yorkers are concerned with adequate airports in these outlying communities, just as the people of the other towns are concerned with the adequacy of New York's airport facilities.

Figure 15 shows similar information for Los Angeles, the largest hub on the west coast. It shows where nearly 3-1/2 million domestic airline passengers came from and left for in 1955. The pattern is about the same as New York's. There were more than 100,000 passengers exchanged with six cities —more than 25,000 with 17 other cities. Los Angeles had traffic with 427 communities.

To pick one specific location common to both charts—Riverton, Wyoming, exchanged more than 200 passengers each with New York and Los Angeles. There is mutual national interest that Riverton, as well as New York and Los Angeles, have adequate airport facilities if there is to be air commerce between them. And Riverton is only one of 550 cities and towns which are now served by scheduled carriers, in which there is a similar interrelationship and interdependence. Similar charts could be developed for any community receiving scheduled service to show this interdependence. These figures are for 1955 when the domestic airlines carried 37 million passengers. In 1956 they carried 42 million. Picture Figs. 14 and 15 in 1970, when we forecast 118 million passengers.

Figure 16 shows how our airport system serves non air-carrier flying. J. I. Case, a farm equipment manufacturer headquartered in Racine, Wisconsin, has a fleet of three aircraft. This is a small fleet compared to some companies. Two planes are twin-engine Beechcrafts, the third is a single-engine Cessna. This map shows the location of nearly 400 airports in almost every state that were utilized by the J. I. Case Co. in the conduct of its business in 1954. All over the country industry is using more than 20,000 aircraft as a business tool. Industries tend to look for an adequate airport just as they are interested in utilities, the availability of labor, and the supply of raw materials, when seeking new sites, and have passed up some communities without adequate airport facilities. In 1955, businessmen in the United States bought more than 4,000 single and twin-engine aircraft worth \$91 million. In 1956 they bought more than 6,000 aircraft that cost well over \$100 million.

Figure 17 shows that small industries, as well as large ones, are using business aircraft. A firm of architects in Bryan, Texas—Caudill, Rowlett, Scott and Associates—has two planes, a Piper Pacer and a small Cessna

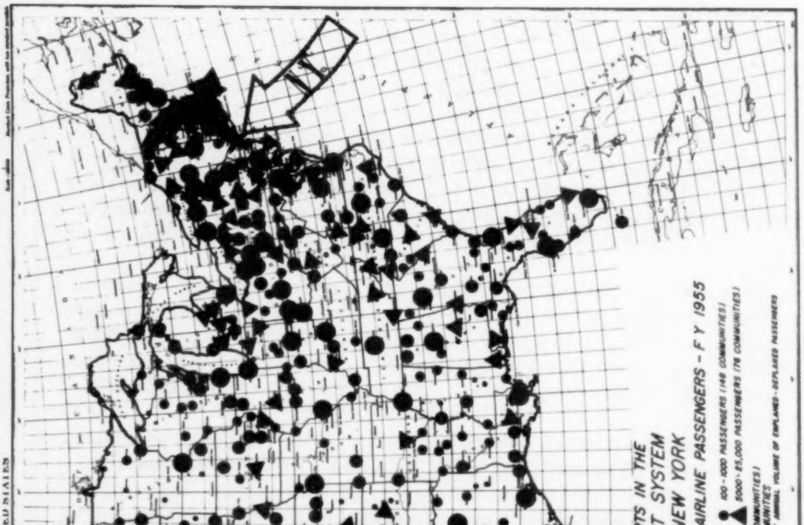
UNITED STATES
AIR COMMERCE AIRPORTS IN THE
NATIONAL AIRPORT SYSTEM
RELATED TO NEW YORK
AS REFLECTED BY VOLUME OF SCHEDULED AIRLINE PASSENGERS - F Y 1955
LEGEND
30-100 PASSENGERS (64 COMMUNITIES)
100-1000 PASSENGERS (149 COMMUNITIES)
1000-5000 PASSENGERS (102 COMMUNITIES)
5000-25,000 PASSENGERS (76 COMMUNITIES)
OVER 25,000 PASSENGERS (55 COMMUNITIES)
TOTAL — 442 COMMUNITIES
DATA FROM C.A.B. AIRLINE TRAFFIC SURVEY SEPT. 1954, EXTRAPOLATED TO REFLECT ANNUAL VOLUME OF EMPLANED - DEPLANED PASSENGERS

Fig. 14

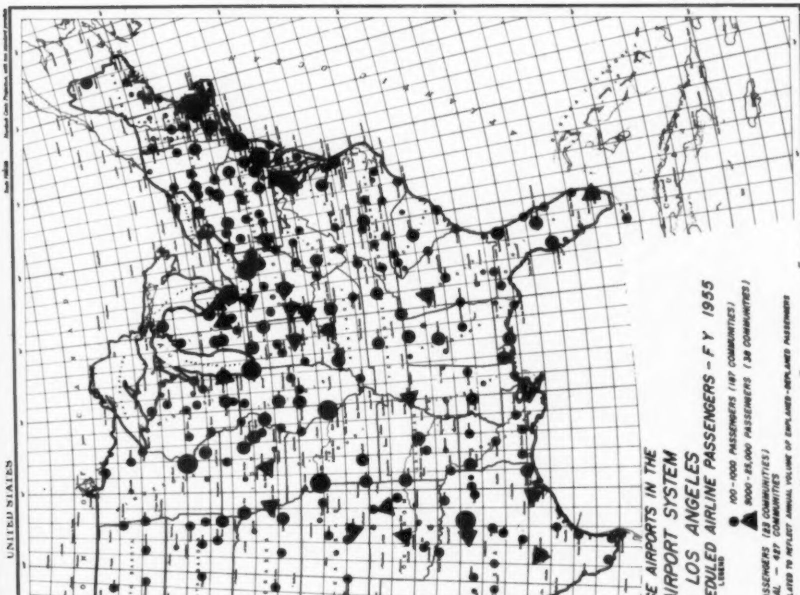
UNITED STATES
AIR COMMERCE AIRPORTS IN THE
NATIONAL AIRPORT SYSTEM
RELATED TO LOS ANGELES
AS REFLECTED BY VOLUME OF SCHEDULED AIRLINE PASSENGERS - F Y 1955

Fig. 15

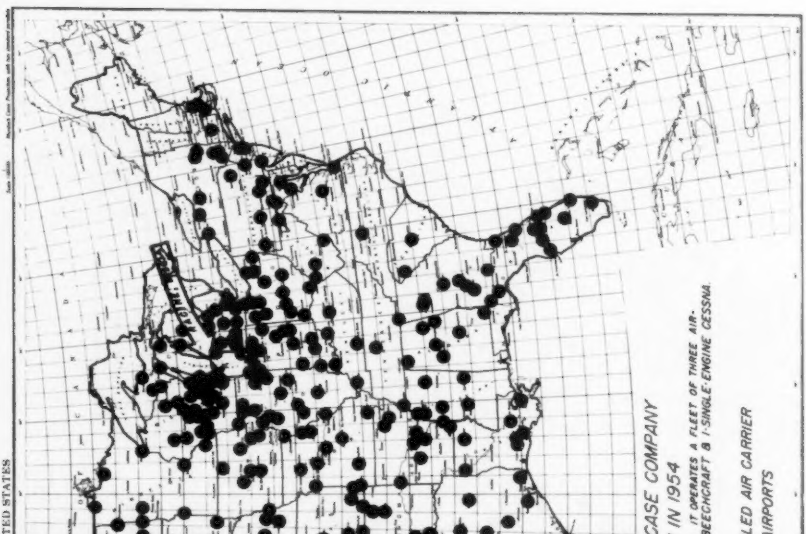
UNITED STATES
U.S. AIRPORTS utilized by J.I.CASE COMPANY
RACINE, WISCONSIN IN 1954
THIS COMPANY BUILDS TRACTORS AND FARM IMPLEMENTS. IT OPERATES A FLEET OF THREE AIR-CRAFT, BASED AT RACINE, WISCONSIN. 2-TWIN-ENGINE BEECHCRAFT & 1-SINGLE-ENGINE CESSNA.
LEGEND
AIRPORTS SERVED BY SCHEDULED AIR CARRIER
GENERAL AVIATION AIRPORTS

Fig. 16

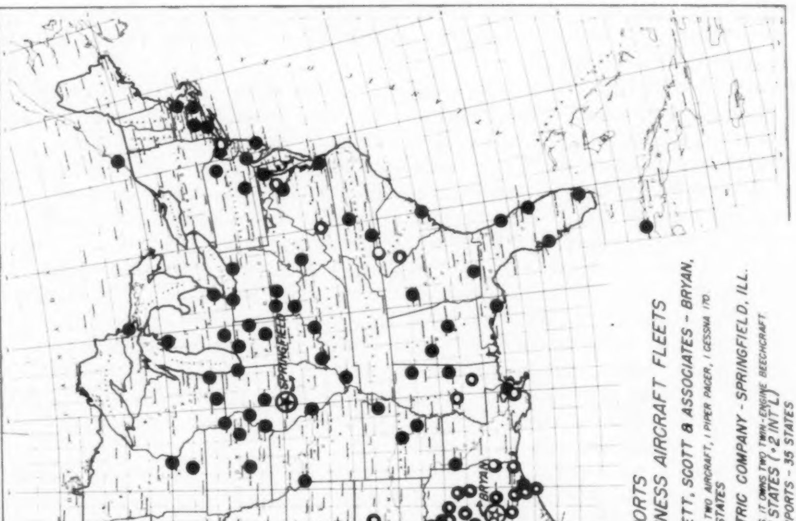
UNITED STATES
SPRINGFIELD
BRYAN
U.S. AIRPORTS
UTILIZED BY TWO SMALL BUSINESS AIRCRAFT FLEETS
AIRPORTS USED BY CAUDILL, ROWLETT, SCOTT & ASSOCIATES - BRYAN, TEXAS. THIS IS A FIRM OF ARCHITECTS. IT OWNS TWO AIRCRAFT, 1 PIPER PACER, 1 CESSNA 170
52 AIRPORTS - 13 STATES
AIRPORTS USED BY SANGAMO ELECTRIC COMPANY - SPRINGFIELD, ILL.
THIS COMPANY MANUFACTURES ELECTRICAL PRODUCTS. IT OWNS TWO TWIN-ENGINE BEECHCRAFT
74 AIRPORTS - 31 STATES (+2 INT'L)
BOTH COMPANIES 118 AIRPORTS - 35 STATES

Fig. 17

which they refer to as being in the Ford or Chevrolet class. In 1955, exclusive of refueling stops, they used 52 airports in 13 states from coast to coast. Sangamo Electric Company of Springfield, Illinois, used 76 airports in 31 states, in 1955, with its fleet of two twin-engine Beechcrafts. Incidentally, recent information from the architectural firm whose activity is shown in Fig. 17 indicates that they now have a larger fleet of faster aircraft and that they continue to service clients in an area larger than would otherwise be possible if they did not fly.

Figure 18 shows that non-airline airports also serve a useful function of more than local interest. This shows the selected results of a survey of only one week's transient activity by business aircraft. Here we see airports serving Sparks, Nevada; Glendive, Montana; Kerrville, Texas; Jacksonville, Illinois; Americus, Georgia; and Chatham, Massachusetts. The transient flights from the last stop before landing and to the first stop after take-off clearly show the far-flung character of the traffic at small airports.

Figure 19 shows similar activity from small airports serving Columbia, California; Ruidosa, New Mexico; Sterling, Colorado; Worthington, Minnesota; Carbondale, Illinois; and Red Bank, New Jersey. These lines indicate only the cities between which there was an interchange of non-stop travel over a one week period, and do not indicate the volume of flying. Figs. 18 and 19 show, however, that even at small airports there is a considerable volume of interstate traffic, and that small airports as well as large ones are needed to make up an integrated airport system.

With Figure 20 we get into the area of system planning. Planning a national system of airports involves, first, the identification of those communities where facilities are required to serve the national interest and second, the detailed planning of facilities within each community. For airports used by scheduled airlines, Fig. 20 serves as a basic planning guide, using two factors —the number of passengers, expressed as a percentage of total U. S. passengers; and the average length of trip, expressed as short, average or long haul. These two factors are bracketed, each bracket indicating a category of airport—Trunk, Express, Continental or Intercontinental. Borderline cases which fall within the top or bottom 10% of any bracket, either passengers or mileage, (shaded), receive special study.

Figure 21 shows data for Lansing, Michigan. Lansing has had a steady growth of passengers, from 8,640 in 1948 to 36,195 in 1955. The passenger curve hovers between the 0.05% line and the 0.10% line. The percentage curve is very uniform but increasing. The length of haul line is in the upper limits of the average haul range. The number of passengers places the airport in the shaded area between Trunk and Express. In view of the ascending percentage curve, Lansing's airport should, we feel, be planned as an Express airport.

Figure 22 is for Grand Rapids, Michigan. Grand Rapids has a steady growth. Its passengers are increasing, from 36,402 in 1948 to 85,824 in 1955. The percentage line shows little variance from the 0.25% line. Its length of haul is in the lower portion of the average haul. This places Grand Rapids in the shaded area between Express and Continental, and since it is traditionally an average haul airport, we feel that an Express airport will accommodate its aviation needs.

Figure 23 shows Columbus, Ohio. Columbus has a passenger increase that is greater than the U. S. average—from 63,887 in 1948 to 239,791 in 1955. The percentage line shows this increase. It has average haul—around 450

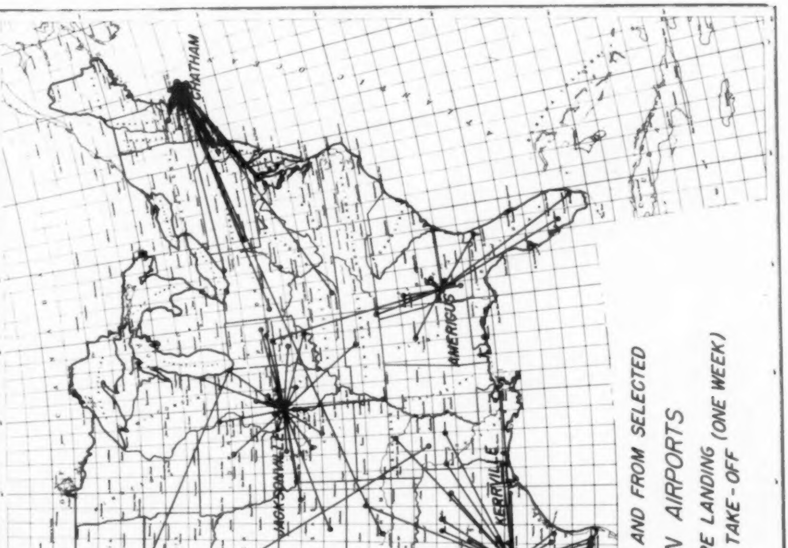
UNITED STATES
TRANSIENT FLIGHTS TO AND FROM SELECTED
GENERAL AVIATION AIRPORTS
LAST STOP BEFORE LANDING
FIRST STOP AFTER TAKE-OFF
(ONE WEEK)
CHATHAM
AMERICUS
JACKSONVILLE
KERRVILLE
GLENDIVE
SPARKS

Fig. 18

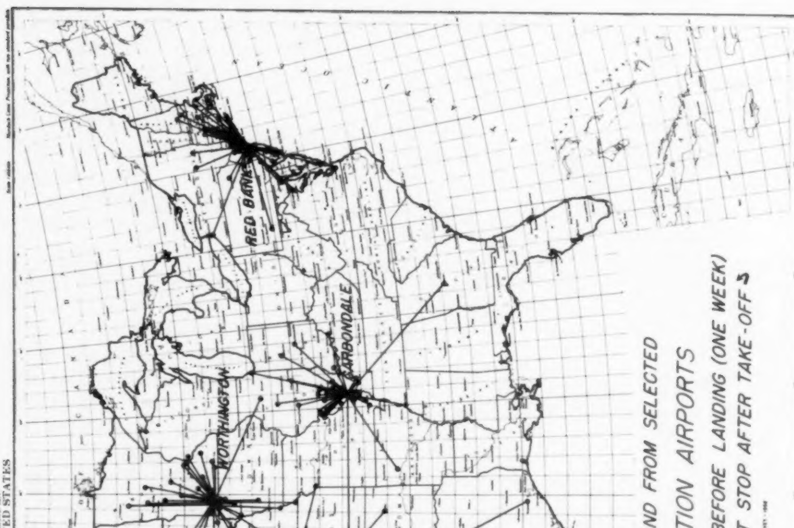
TRANSIENT FLIGHTS TO AND FROM SELECTED
GENERAL AVIATION AIRPORTS
LAST STOP BEFORE LANDING (ONE WEEK)
FIRST STOP AFTER TAKE-OFF
UNITED STATES
RED BANK
CARBONDALE
WORTHINGTON
STERLING
RUIDOSA
COLUMBIA

Fig. 19

TYPE OF HUB	1954 ENPLANED PASSENGERS %	1954 ENPLANED PASSENGERS NUMBER		SHORT HAUL (UNDER 300 MILES)	AVERAGE HAUL (300 TO 600 MILES)	LONG HAUL (OVER 600 MILES)
				270	330 540	660
LARGE HUBS	1.00 & OVER	OVER 317,000	349,000	CONTINENTAL	INTERCONTINENTAL	INTERCONTINENTAL
MEDIUM HUBS	0.25 TO 0.99	79,000 TO 317,000	285,000 87,000	EXPRESS	CONTINENTAL	INTERCONTINENTAL
SMALL HUBS	0.10 TO 0.24	32,000 TO 79,000	71,000 35,000	TRUNK	EXPRESS	CONTINENTAL
SMALL HUBS	0.05 TO 0.09	16,000 TO 32,000	29,000 18,000	TRUNK	TRUNK	EXPRESS
NON-HUBS	UNDER 0.05	UNDER 16,000	14,000	TRUNK	TRUNK	TRUNK
				270	330 540	660

Fig. 20

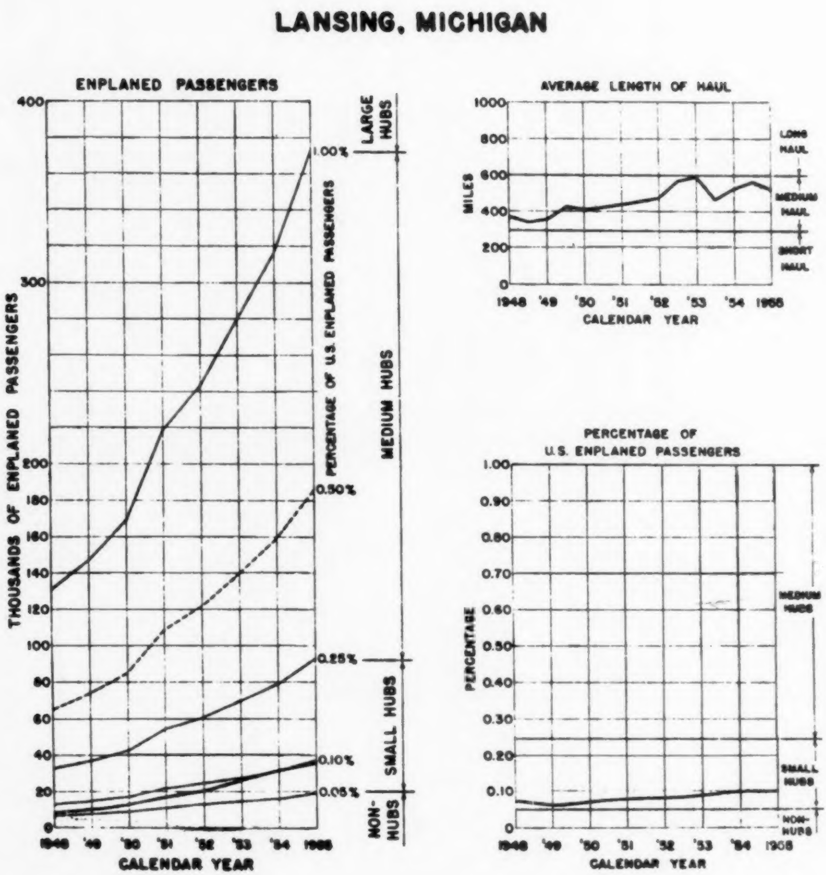
LANSING, MICHIGAN
ENPLANED PASSENGERS
THOUSANDS OF ENPLANED PASSENGERS
PERCENTAGE OF U.S. ENPLANED PASSENGERS
1.00%
0.50%
0.25%
0.10%
0.05%
LARGE HUBS
MEDIUM HUBS
SMALL HUBS
NON-HUBS
CALENDAR YEAR
AVERAGE LENGTH OF HAUL
MILES
LONG HAUL
MEDIUM HAUL
SHORT HAUL
PERCENTAGE OF U.S. ENPLANED PASSENGERS
PERCENTAGE

Fig. 21

GRAND RAPIDS, MICHIGAN

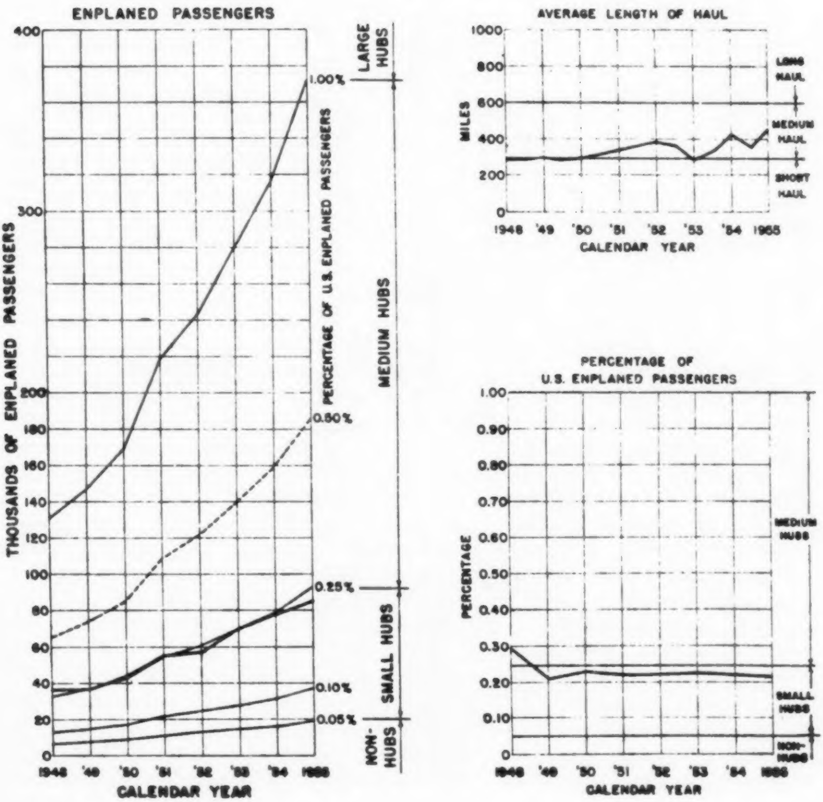

Fig. 22

COLUMBUS, OHIO

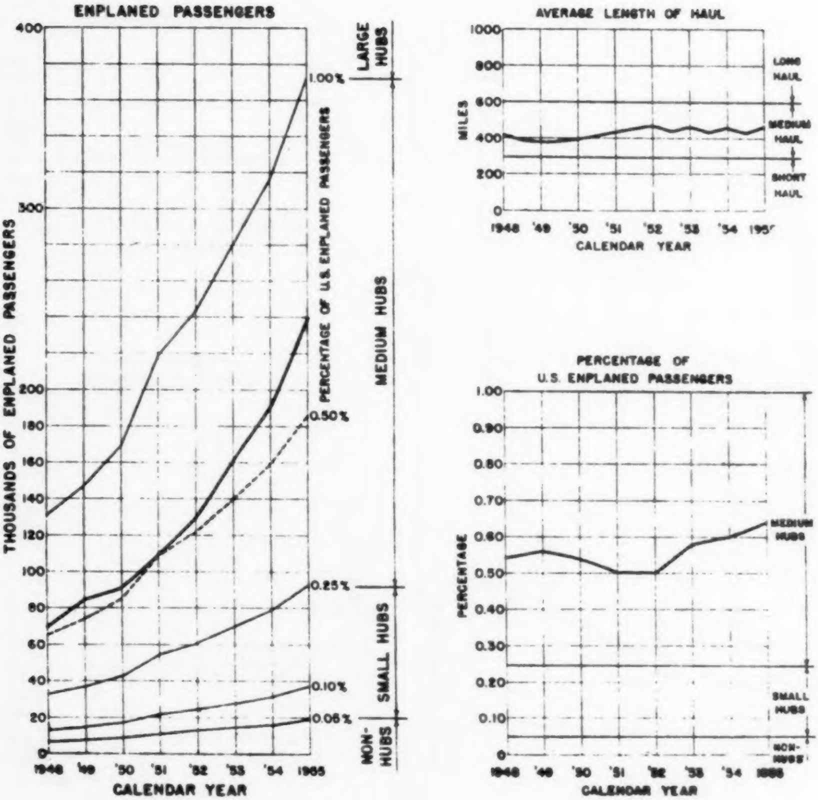

Fig. 23

miles. The chart clearly indicates that a Continental airport is required.

Figure 24 shows Charlotte, North Carolina. Charlotte shows an increase well above the U. S. average—from 52,790 passengers in 1948 to 280,331 in 1955. The percentage line bears this out. It rose rapidly until 1952 and then levelled off at about 0.8%. Its length of haul is average. These factors indicate the need for a Continental airport.

Figure 25 shows Toledo, Ohio. Toledo for years was served with an inadequate airport which could not accommodate aircraft larger than the DC-3 type. Its new airport was opened in 1954. Note that the number of passengers, although increasing, lagged behind the U. S. average as expressed by the 0.25% line. The volume increased in 1954 when the new airport was opened, and sharply increased in 1955 as better service was inaugurated. The percentage line indicates this sharp increase. We feel that because of its location and population, it will continue to increase. Toledo is in the upper limits of the average haul. This places it in the shaded area between Express and Continental but because it has substantial population, we expect traffic to increase, now that adequate airport facilities are available. We therefore feel that Toledo should plan for the larger or Continental category.

Where there is no history of passenger activity, we estimate the air carrier airport requirements from a comparison of the community with other communities of similar size and the same economic character.

The CAA criteria must be applied with judgment. Abnormal growth or distance trends, and the route structure of the air carriers serving a community, are factors that must be given special consideration.

We also have guidelines for planning general aviation airports and criteria to determine the number of airports which a specific community will require.

With Figure 26 we get into the area of military aviation. So far, military activity has not been cited, but it is a factor in civil airport planning where there is going to be joint use. Fig. 26 shows the extent of military use of civil airports where the military services have installations and base military aircraft. A total of 304 installations of all types are located on 222 civil airports. Sixty-four of these civil airports have military jets based on them.

Figure 27 shows how the use of civil airports by military aircraft has increased. This is a graph showing total traffic at all airports with CAA towers. Military traffic has increased from 9% of the total aircraft movements in 1947, to 26% in 1955. Air carrier flying and civil itinerant flying have also increased. Civil local flying shows a considerable decrease in the 1947-1952 period. This is due to stopping the G. I. Veterans Training Program and the transfer of some of the remaining activity from busy terminals to nearby small airports. It is significant, however, that on the average of one out of four operations at airports with CAA towers is by a military aircraft.

The CAA's estimate of the airports required to form a national system is expressed in the National Airport Plan, revised annually to reflect, on a forecast basis, those airports which are necessary for a national system of civil airports adequate to accommodate all types of civil aviation in the foreseeable future. The National Airport Plan shows only the over-all designation of the category of airport ultimately required to serve the national needs of civil aviation at a specific location.

This designation of size furnishes the community with a general guide for its own future airport master planning, and with other planning data published by CAA, it can develop detailed forecasts, analyses, and over-all plans. Here

CHARLOTTE, N.C.

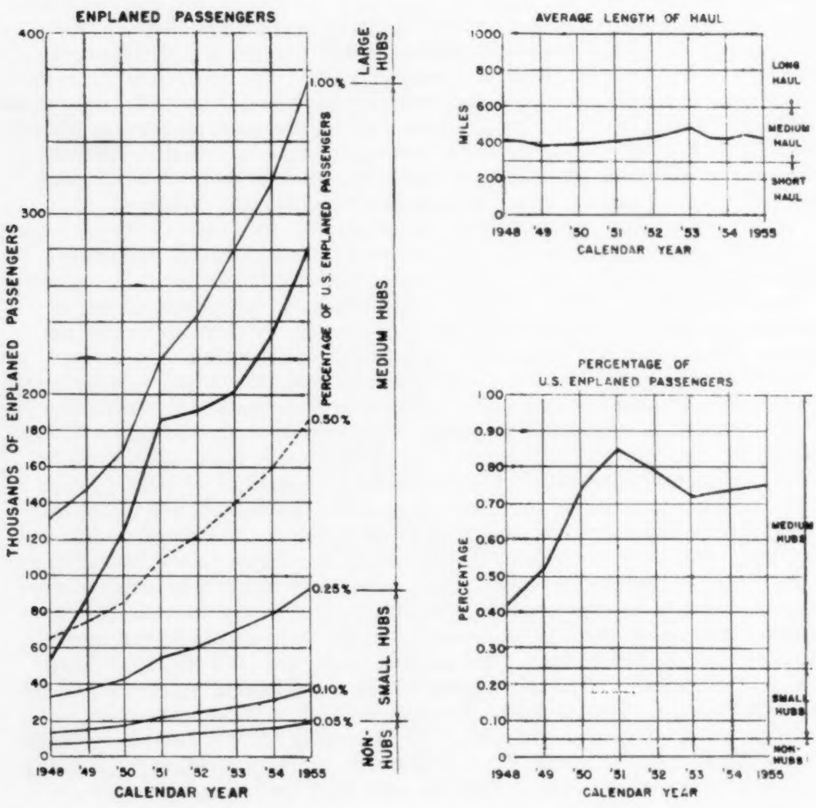

Fig. 24

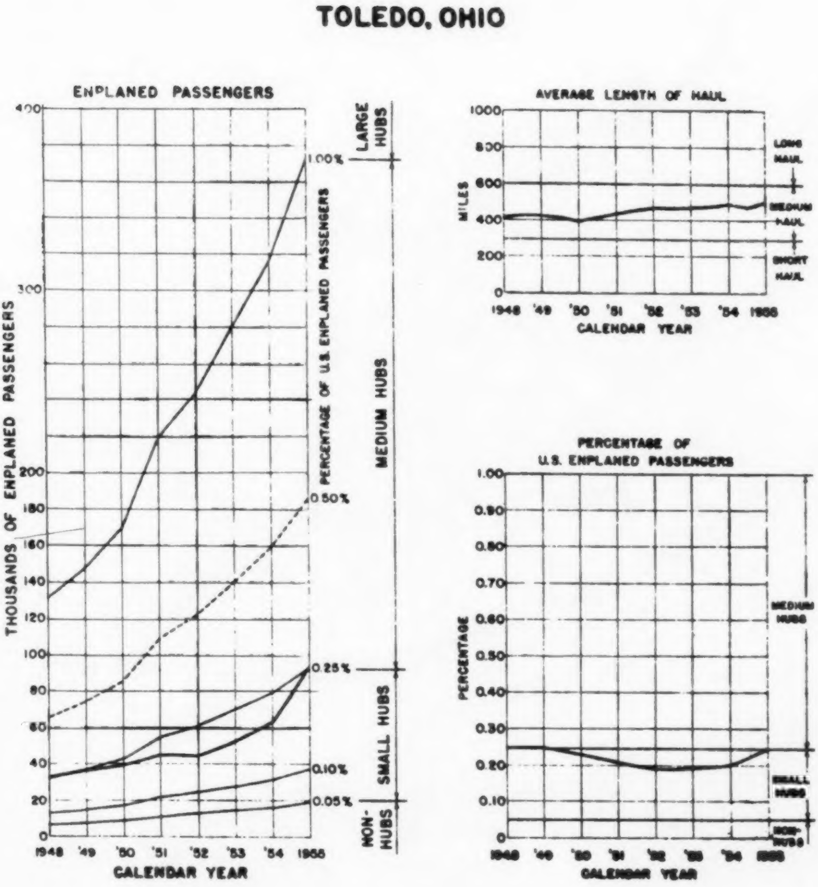
TOLEDO, OHIO
ENPLANED PASSENGERS
THOUSANDS OF ENPLANED PASSENGERS
PERCENTAGE OF U.S. ENPLANED PASSENGERS
1.00%
0.50%
0.25%
0.10%
0.05%
LARGE HUBS
MEDIUM HUBS
SMALL HUBS
NON-HUBS
CALENDAR YEAR
AVERAGE LENGTH OF HAUL
MILES
LONG HAUL
MEDIUM HAUL
SHORT HAUL
PERCENTAGE OF U.S. ENPLANED PASSENGERS
PERCENTAGE

Fig. 25

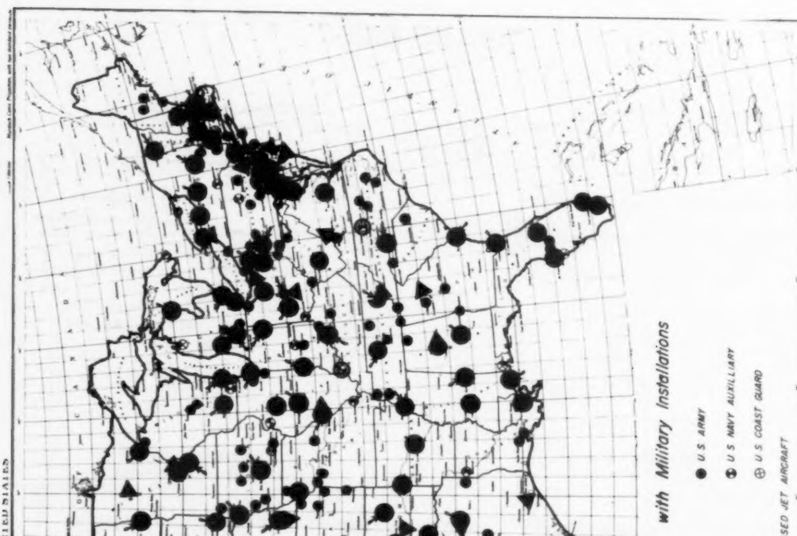
UNITED STATES
CIVIL AIRPORTS with Military Installations
U S AIR FORCE
U S NAVY
U S AIR NATIONAL GUARD
U S ARMY
U S NAVY AUXILLIARY
U S COAST GUARD
BASED JET AIRCRAFT

Fig. 26

TRAFFIC VOLUME AT CIVIL AIRPORTS WITH CAA AIRPORT TRAFFIC CONTROL TOWERS

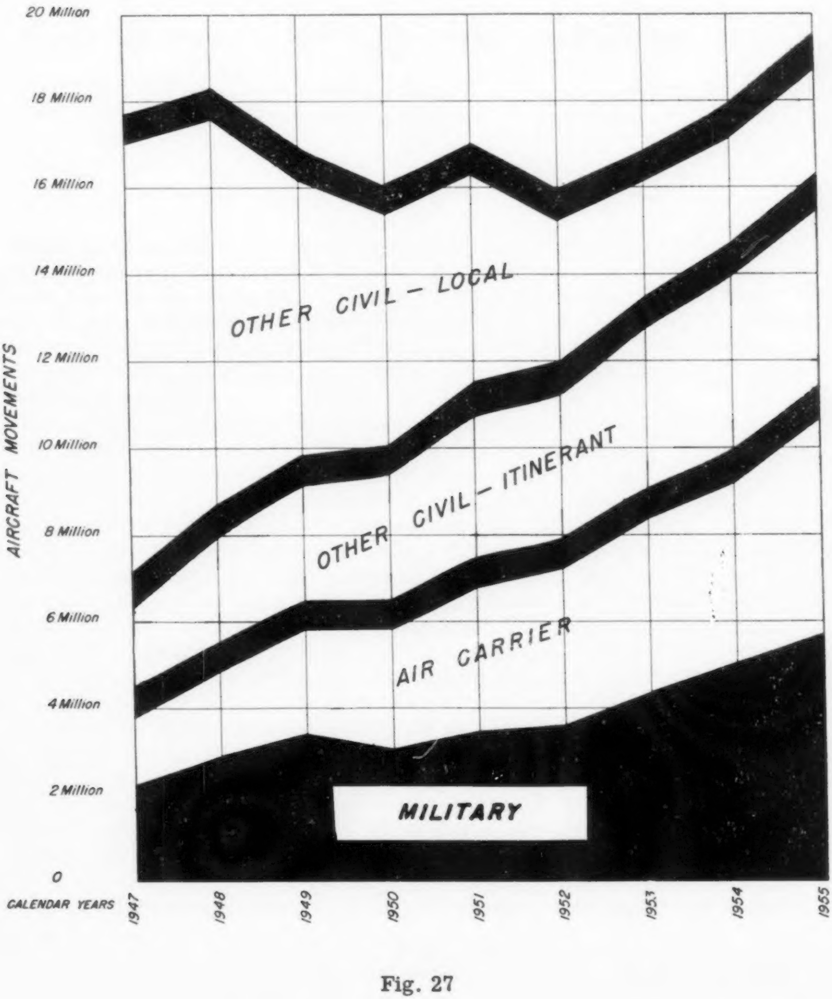

Fig. 27

is where local master planning takes over.

With the jet age upon us, and with the increased traffic that is accompanying the jet age, each community is finding it necessary to examine most carefully its master planning processes and, of more importance, is finding it necessary to review its master plan frequently so that it can rest in assurance that its plans are valid and, equally important, adequate.

Paper 1484 December, 1957 AT 2

Journal of the
AIR TRANSPORT DIVISION
Proceedings of the American Society of Civil Engineers

APPROACH AND RUNWAY LIGHTING FOR JET-AGE AIRCRAFT [a]

Howard J. Fry[1]
(Proc. Paper 1484)

INTRODUCTION

The topic of approach and runway lighting should not be restricted to merely jet aircraft, because such lighting is important to the conventional aircraft, as well as for the jet. The actual need for efficient visual aids to assist the pilot in landing in reduced visibility conditions, or during the hours of darkness, has been present since flying was in its infancy. The problem has become a little more complex and the requirement more urgent with high-performance aircraft.

There have been developed numerous nonvisual approach systems devised to position the pilot, so that he can complete his landing visually. However, until we get a completely automatic landing device of some nature, the pilot, at some point on the approach, is still going to have to "take over" visually and complete the actual touchdown and landing roll. In the military, especially, with the advent of the high-performance aircraft with increased landing speeds, and the requirement for all-weather operations, this problem has become one of major importance. Other than actual combat, the most critical demand upon the pilot's skill is during transition from instrument to visual flying in low ceiling and restricted visibility conditions. Reaction to light patterns must be automatic and natural, requiring a minimum of effort and interpretation.

The need for lights off the approach end of runways in the maneuvering area for all aircraft has been adequately justified in the past, and it has been agreed that adequate visual aids in the maneuvering area are mandatory to safely complete a landing under extremely low visibility conditions. Such an approach system is presently installed at March Air Force Base, California.

The writer appreciates the opportunity to present some of the problems that have been experienced by the Air Force in jet operations over the last few years. These experiences have clearly brought in focus the urgent need

Note: Discussion open until May 1, 1958. Paper 1484 is part of the copyrighted Journal of the Air Transport Division of the American Society of Civil Engineers, Vol. 83, No. AT 2, December, 1957.

a. Paper prepared for presentation at Jet Age Airport Conference, New York, N. Y., May, 1957.

1. Colonel, Director of Safety Fifteenth Air Force Strategic Air Command March Air Force Base, California.

for improved visual aids on the approach to runways. There will also be described the improved system which has been installed at March Air Force Base, California. The installation at March is the pilot model for the Air Force, to determine the suitability for acceptance as a national standard.

The primary objective of the test is to evaluate an approach lighting system which will facilitate landings of high-performance aircraft under restricted visibility conditions efficiently and safely.

Little consideration has been given in the past to the penalty of confusion on the final approach. Any lighting system was felt to suffice in the number of clues necessary to the pilot. In the past 10 years we have had numerous systems installed. In reality, a lack of understanding of the necessary clues gave way to the poor and nonstandard lighting systems in use and being installed today. Clues designed for pilots must be well conceived from the instant a transition is made, wholly or in part, from instruments. This is in the maneuvering area prior to reaching the runway threshold. It should be provided in a manner which will allow the pilot to proceed in for the landing, with few actual decisions to make. Most clues should appeal to the automatic reaction which can be done in a minimum of time. For example, adequate centerline lighting requires an automatic reaction towards its maintenance as a flight path. On the other hand, a pilot, noting an extension of a row of side lights only, will have to decide whether he is over the runway, or still in the approach zone. Any small decision on the approach requires at least half a second. In addition, reaction time may be as long as half a second. Therefore, it is of the utmost importance to reduce the number of these decisions to a minimum.

You can readily see that high approach speeds further complicate the problem and will affect the accident exposure on the approach. It is generally agreed that the heart of any guidance system is the centerline guidance to the threshold, which is the present national standard for the commercial carrier, or configuration A.

A very important addition to this system is the strobeacon condenser discharge light, to give an added initial identification, such as is installed at Idlewild (New York, N. Y.) and Newark (N. J.) Airports. This high-intensity, short-peak-duration light has become even a more important part of the system for the high-performance aircraft in gaining added identification time of four to nine seconds prior to seeing the steady burning lights during this most critical time of our approach, and provides added maneuvering space for a better degree of safety. Although this centerline guidance is agreed as mandatory for low-visibility landings, the military has been forced to terminate the centerline guidance 1,000 feet from the threshold, and continue just side guidance to provide a cleared undershoot area. This area must be clear, not only to provide adequate space for runway barrier chains to be extended into, in the event of an aborted take-off for a fighter aircraft, but also as an undershoot area or overrun area for added safety in aborting a take-off, or undershooting the landing.

This underrun area has proved of great value in reducing aircraft damage for the military; however, it has posed a problem in obtaining centerline lighting to the threshold for low-visibility approaches. The possibility of touching short on an approach is greater in aircraft of the B-47 type, as the initial approach speed is close to stall speed. It is easy to over-control slightly, which increases the stall speed very rapidly on sweptwing aircraft, resulting in an inadvertent touchdown short of the runway. The

commercial carrier presently does not have this problem in the same magnitude as the military; however, it will be a problem to the commercial carrier in the coming age of civil jet transports.

The configuration B, which is presently the standard configuration for the military, gives you a minimum of centerline guidance, then puts you over the "black hole," or void, which is actually the underrun area, and is an invitation to land short.

The problem of centerline guidance to the threshold versus unobstructed overrun, or configuration A and B of the present national standard, has been solved by use of the Elfaka flush-lighting unit. A flush light is required within the clear zone to remove the USAF objection of having electrical fixtures protruding upward where the anchor chains used at the fighter bases for barriers could possibly damage the system or conceivably short out and cause fire in this area. Flush lights are installed in the overrun at March Air Force Base.

There is really no question concerning the need of lights for the approach end of runways in the maneuvering area for aircraft with increased landing speeds. The need has been adequately justified in the past and it is agreed that added visual clues are mandatory to safely complete the landing with the present-day high-performance type aircraft.

Headlines and pictures depicting aircraft crashes in the daily newspapers bring home again and again the need for adequate lights for guidance in the maneuvering area. Actually, in the military, USAF-wide, during the past 48 months, 10 accidents listing inadequate approach lighting as a primary cause factor have occurred. Since January 1953, 13 aircraft within the Strategic Air Command have been totally destroyed in accidents in which the lack of adequate lighting could have been a contributing cause factor. These accidents have resulted in 50 fatalities and approximately 27 million dollars replacement costs.

Since becoming concerned with runway approach lighting, the United States Air Force has started to look a little more closely at the accidents which occurred during landing operations. As a result, more and more cases are being found where adequate lights would possibly have alleviated the accidents.

The Air Force prototype installation at March Air Force Base is similar to numerous other systems throughout the United States, with two exceptions. It includes for the first time, for the military, in the United States, the condenser discharge light, or strobeacon, which gives the very necessary added initial identification for high-performance aircraft. This ultrahigh-intensity flashing unit is placed at each bar unit and continues in the flush units in the underrun area. These beacons flash in precise sequence and appear to be a vivid ball of blue-white light traveling some 3,600 miles an hour towards the runway every half second, and, to quote Major General Crabb, Commander, Central Air Defence Force, who made low approaches over the new installation in April 1957: "The strobe light is one of the finest pieces of equipment ever invented."

The other advancement is the hardware that has allowed the military to obtain the much needed guidance to the threshold and still have a cleared overrun area, the Elfaka flush light. Actually, neither of these additional aids are new. The strobeacons have been in use for considerable time at Newark and at Idlewild Airports; however, this is their first use within the military, and initial pilot reaction is that they are mandatory. The flush unit is not new; it has been used, in a slightly different model, by the Royal Dutch

Airlines at Schiphol Airport, Amsterdam, for a number of years without difficulty, and the 32d Day Fighter Squadron, stationed at Soesterberg, Holland, has operated over the Elfaka lights for many months without any reported difficulty.

The suitability of this flush light within heavy snow areas is unknown; however, it is currently programmed to install these lights with an integrated approach system, consisting of the approach system with a continued—narrow gauge lighting within the runway itself, at Dow Air Force Base, Maine, which will provide us with additional data.

The initial test at March Air Force Base shows that the Elfaka flush light definitely has merit, especially in the moderate climates. The next few illustrations will give a better understanding of the system as installed at March Air Force Base.

The underrun area at March Air Force Base is of primary importance, and Figure 1 shows the initial construction of the flush units within the underrun area. This is one of the barrettes in the underrun area, with five Elfaka units to each barrette. Four of these units house the steady burning lights, and the center unit, the strobeacon. The concrete housings are precast and placed in this position.

In Figure 2 is shown the Elfaka unit being placed in the concrete housing, which provided the necessary support housing within the underrun area.

Figure 3 is a different view of one of the barrettes, showing the concrete housings with the Elfaka grills installed for a complete barrette. There are 7 of these within the underrun area, with the 8th and last one consisting of 11 units, which is the termination bar of the centerline configuration.

Fig. 1. Initial Construction of Flush Units.

Fig. 2. Elfaka Unit Being Placed in Concrete Housing.

Fig. 3. One of the Barrettes.

Figure 4 shows the overrun being completed and a workman is working on the strobe light unit, which is contained in the center of each of the bars within the underrun area. This strobe light provides identification guidance to the termination bar, which is 200 feet short of the actual threshold.

In the underrun area a chip-and-seal method was used to stabilize the dirt around the units; however, this underrun will normally be a hard surface underrun.

A flush unit in the termination bar, was inadvertently tested about two weeks after they were turned on. A B-47 touched down approximately 250 feet short of the threshold, running across the light in the termination bar, and a considerable amount of rubber was left on the grill of the light; however, there was no damage to the light, and, what is more important, no damage to the aircraft, such as we would have sustained with an elevated fixture.

Since the system at March Air Force Base is a prototype system for the Air Force, it has been constructed so that we may turn off the side lighting to make a better evaluation on the amount of the side lighting that is absolutely necessary for low visibility approaches. (Fig. 5)

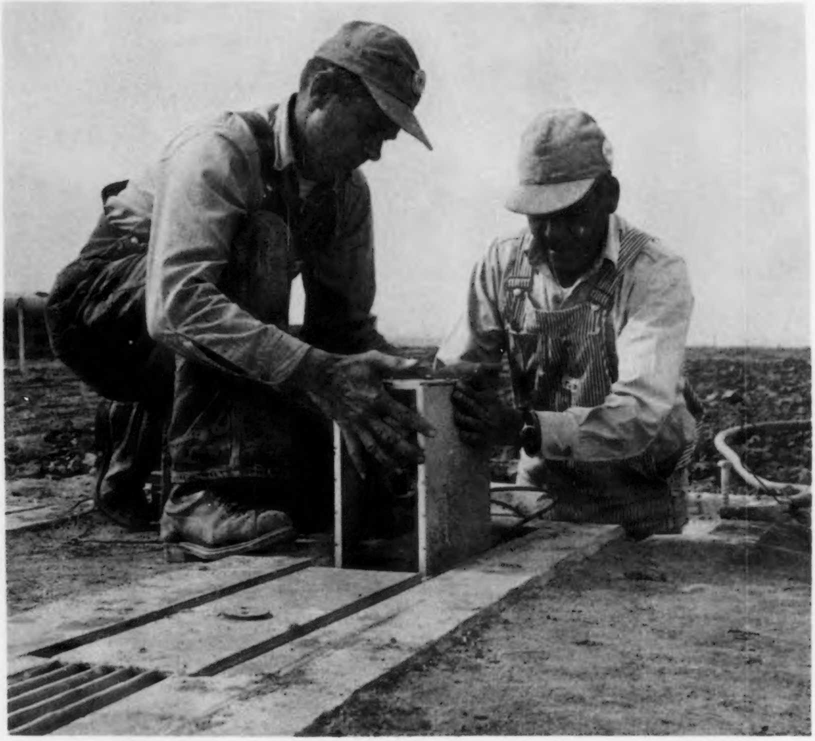

Fig. 4. Strobe Light Unit Being Installed.

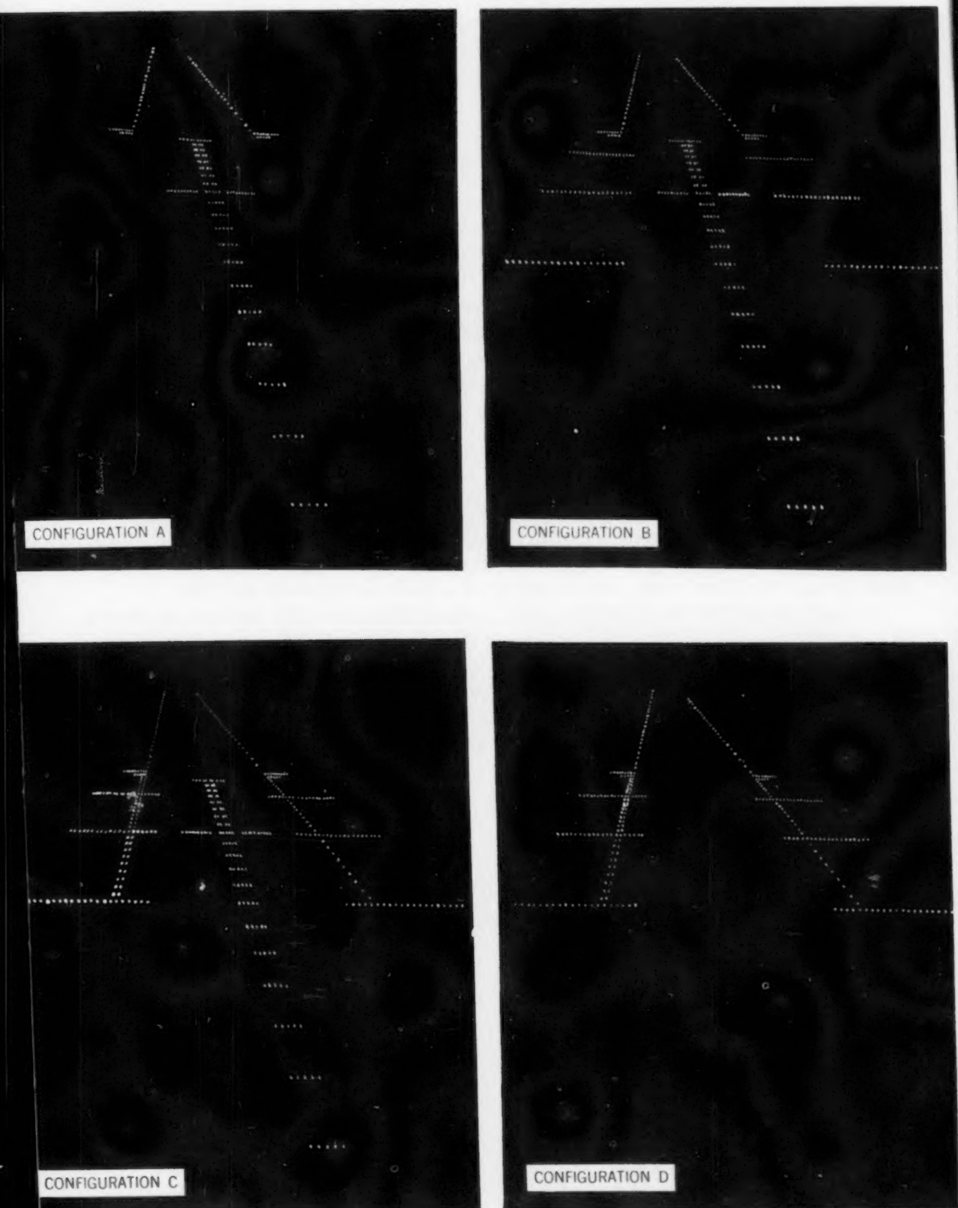

Fig. 5. Approach-Lighting Configurations.

The following photographs will give a better view of how the approach system appears under varying visibility conditions. These pictures were taken during the opening program of installation at March Air Force Base, and will show closer views of the components of the system and late model aircraft making approaches under good visibility. Figs. 6 through 9)

CONCLUSIONS

The evaluation of the approach system at March Air Force Base should provide us with the desired approach guidance; however, the visual approach aids are of little benefit unless we can complete the landings. Before an all-weather Air Force can be achieved, better runway guidance is required. Narrow gauge lighting, or flush lighting actually within the runway, appears to be the best answer to allow us to go from our approach guidance to the runway itself, and complete the landing. Although the installation of the narrow gauge system with an Elfaka light in the runway, especially where the runway is presently installed, is considered expensive, it will not compare with the potential loss of equipment entering the Air Force and commercial inventories now, not to mention the possible loss of life.

To further test the principles of the narrow gauge runway lighting, tests have been under way at Andrews Air Force Base by the Civil Aeronautics Administration, and Dow Air Force Base has been selected and programmed for installation of a complete approach lighting system, plus a narrow gauge landing mat for 3,000 feet, which will give a truly integrated system.

Implementation throughout the Air Force of the approach lighting systems, as installed for suitability test at March Air Force Base, and adoption of the flush lighting to fill up the "black hole," after passing the approach end of the runway, which is scheduled for construction at Dow Air Force Base, will offer a major contribution in the campaign for safer air operations, as well as lead to more economical operation as a result of fewer weather diversions.

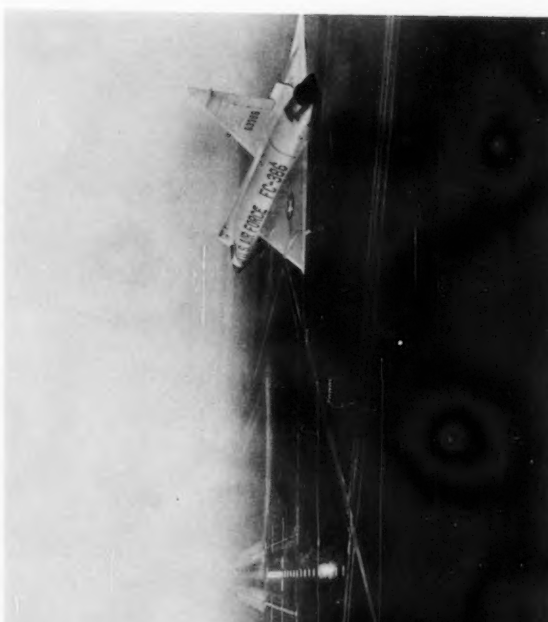

Fig. 6. F-102 Approaching March Air Force Base.

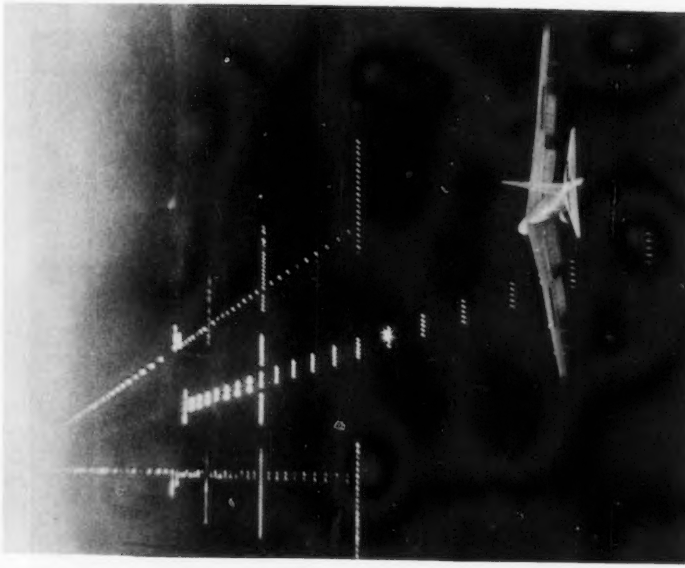

Fig. 7. B-52 Over March Air Force Base.

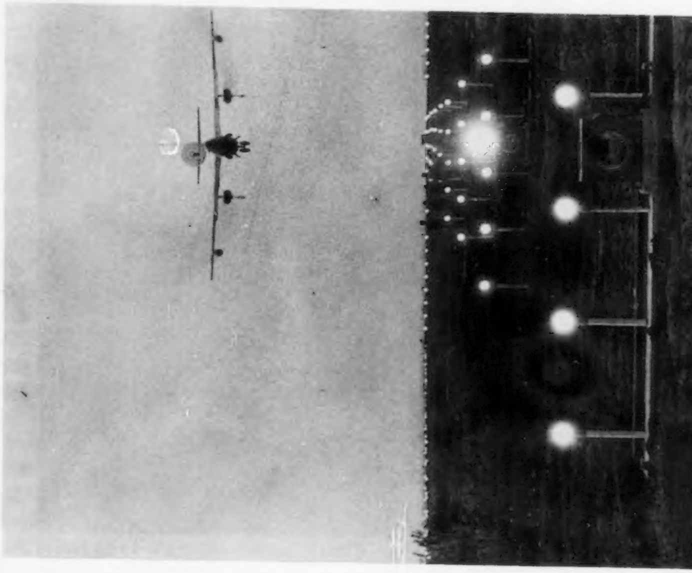

Fig. 9. B-47 1500 Ft from Runway Threshold.

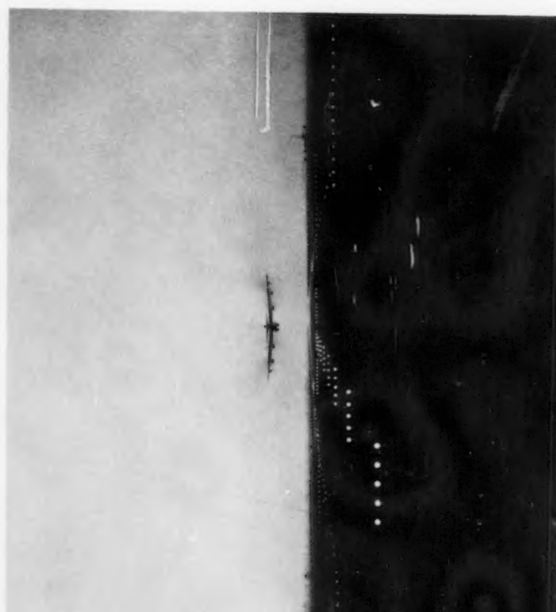

Fig. 8. B-52 on Final Approach.

Paper 1485 December, 1957 AT 2

Journal of the

AIR TRANSPORT DIVISION

Proceedings of the American Society of Civil Engineers

CONTENTS

DISCUSSION
(Proc. Paper 1485)

USAF AIRFIELD PAVEMENT PROBLEMS IN THE JET AGE[a]

Discussion by Frank H. Gardner and Carlton H. Bascom

FRANK H. GARDNER,[1] M. ASCE.—In this paper Mr. Leslie has shown that the case being presented against flexible paving falls into two distinct phases. The first phase is based on the known susceptibility of asphalt paving to damage under excessive jet-fuel spillage and prolonged direct exposure to jet-after-burner blast. The asphalt industry, through The Asphalt Institute, has conceded that flexible pavement might deteriorate rather rapidly if subjected to abuse in this manner and agreed, with certain reservations, to the conclusion reached at the 1954 Congressional hearing: that so-called "critical" areas might properly be paved with cement concrete and the unquestioned economy of asphalt paving be waived.

The reservations expressed by The Asphalt Institute during the hearing were well founded. The Institute was dubious of the term "critical areas." It could be applied to vast areas not directly affected by fuel spillage and jet blast. As expected, the term was applied to the entire apron area although the fuel and blast problems were limited to fueling and service areas.

The Institute also did not feel that a full 1,000 feet at runway ends were subject to serious jet blast. The Institute regarded the Navy practice of paving only the 300-foot extremities with concrete as a sensible precaution.

The reaction of the Air Force to this 1954 conclusion was curious. The Air Force accepted this new criteria as a tactical advance, and nothing more. In a letter to the chairman of the Congressional committee, John M. Ferry, Special Assistant for Installations, Department of the Air Force, wrote:

> "While we are completely convinced that 100 percent concrete paving has a definite advantage as compared to a combination of concrete in the critical areas and asphalt in the non-critical areas, we have been unable to collect adequate engineering backup, as reflected by maintenance costs, to substantiate this view. . ."

Any doubt about the ultimate aim of the Air Force was thereby dispelled.

Early in 1955 the Air Force revealed that some asphalt airfield pavements were rutting and showing other visible signs of distress under heavy wheel loads and channelized traffic of the B-47 jet bombers. The Air Force therefore spread the phrase, "critical areas" to include all primary taxiways. When asked for specific instances of pavement failure, the Air Force cited 7 installations of some 350 Air Force bases scattered around the world. Investigation by Asphalt Institute engineers reduced this 7 to 3 at which there was actual pavement distress that could not be corrected with routine maintenance.

a. Proc. Paper 1480, December, 1957, by George W. Leslie.

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On the three bomber fields where definite indications of pavement distress were evident, the cause in each instance was traced directly to faulty pavement design or construction.

These disclosures did not alter Air Force policy. Asphalt paving was relegated to the interior portions of the main runways and, within a year, the Air Force extended the definition of "Critical Areas" to include all "primary pavement at all "multi-purpose" bases. That is, the Air Force could define a freighter field as a bomber field and, by applying the "critical" term to all "primary" pavement, could (and did) relegate asphalt paving to training fields, temporary airstrips, and occasional shoulder and over-run areas.

Meanwhile, an unfortunate test performed at Kelly Air Force Base was used by the Air Force to consolidate its position. A test section of asphalt pavement developed wheel impressions after 9,000 test load coverages of simulated B-47 traffic in a test that called for 30,000 coverages. By all engineering standards, the Kelly test was a poor one. Although the test pavement itself was soundly conceived and carefully constructed as a standard heavy-duty airfield pavement, it contained an excessive amount of asphalt for the extreme conditions of the test. It was a pavement designed for the standard 1500 test coverages at very high pavement temperatures, but the test criteria increased this load factor twenty-fold---to 30,000 coverages. Further, all test traffic was applied at extremely high pavement temperatures, not a "fair" test for an asphalt pavement any more than it would be "fair" to subject a concrete pavement to alternate thawing and freezing conditions under test traffic. Finally, and most important, the paving mixture for the Kelly test was too rich and the test results were therefore entirely predictable.

An interesting and significant sidelight on the Kelly test is the fact that the faulty test section was replaced immediately after the test with a standard heavy-duty asphalt pavement and has been in constant operational use since mid-1956, performing handsomely. In all fairness, Mr. Leslie should have included this supplemental (and critically important) information.

A few weeks after the Kelly test was suspended, the Corps of Engineers constructed test panels at the Waterways Experiment Station, using a leaner mix, and repeated the Kelly test pattern. This pavement, designed and built to meet the special requirements of the test, survived 30,000 coverages of the test vehicle without appreciable distress.

Another subject that is missing in Mr. Leslie's summary of the military airfield situation is any reference to cement concrete failures. Surely, one cannot believe that pavement distress at military airfields is limited to flexible pavements. Many thousands of square yards of rigid pavement are being replaced or resurfaced annually on the fields. There must be a reason, and the reason is pavement failure. Instead Mr. Leslie refers confidently to slabs of ever-increasing thickness to meet the challenge of ever-increasing aircraft loads. When he mentions the building of slabs 18 to 22 inches thick to meet the requirements of to-day's heavy bombers, one must plead for some restraint.

The solution is not that easy. Paul T. Sutton, pavements engineer at the Air Proving Ground, Eglin Air Force Base, Florida, in a paper delivered at the USAF Pavement Maintenance Conference at Colorado Springs, Colorado, in May 1956 said:

> "These extremely thick slabs are going to present problems due to internal stresses set up from warping caused by temperature differential of

the top and bottom surfaces. To eliminate this problem, as well as to effect a possible economy in construction, the traditional concept of rigid pavements as a slab whose strength is increased by adding to its thickness might well be discarded in favor of reinforced or prestressed sections in the channelized areas."

Incidentally, Mr. Sutton also had a few pertinent remarks to offer on the general quality of asphalt pavements and it might be appropriate to submit them at this point:

"Damage to asphaltic concrete runways from jet blast or spillage is only slight. The few cases of rutting of bituminous concrete pavements in the channelized areas from bicycle-type landing gear, along with some surface flushing which has occurred, are the exceptions which can be eliminated by the proper design mix and good control and inspection during construction."

In conclusion attention should be paid to the remarks offered in September 1956 by James T. Pyle, CAA Administrator, at the Jet-Age Conference in Spokane, Washington, who said:

"Every airport manager is interested in the effect of the heavy jets on his runway paving and the paving of his taxiways and run-up pads. It may be necessary to add to the paving thickness at some airports, particularly if the jet transports are heavily loaded. However, the wheels of the new aircraft are widely spaced so that they spread the weight over large areas of the pavement and the runway problem, from a load-bearing standpoint, does not appear to present us with any immediate crisis. The effect of jet blast and spilled fuel on paving is something which we are investigating carefully since we are deeply concerned with both new and existing construction. From what we have learned to date, it does not appear that either the blast or an occasional bit of spillage is going to do any great amount of damage."

W. J. Turnbull, Chief of the Soils Division at the Waterways Experiment Station, U. S. Army Corps of Engineers, in Proc. Paper 1479 has illustrated the fine performance record of asphalt pavements under proto-type jet aircraft traffic.

CARLTON H. BASCOM.[2]—In the paper by Mr. Leslie there is the suggestion that in no area at an airfield is an asphaltic concrete pavement suitable. Firstly, it implies that pavements are too susceptible to destructive effects of fuel oil. This conclusion is erroneously derived from tests on improperly designed pavement, without the protection of sealers. A dense design of surface with sealer is highly effective and presents less problem than the joints in rigid pavements.

Secondly, based on failure of sections of improperly designed pavement it is concluded that no flexible pavement design will support the necessary loads. This is not supported by the many pavements of more suitable design which continually carry loads at high frequencies. Designs making use of proper sub-grade, base pavement and shallow depth of suitable dense graded surfacing will be found satisfactory for any loading requirements. Why spend

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excessively for rigid pavement? Let us not go overboard in specifying the loading requirements.

Thirdly, the flexible pavements are asserted to be unable to withstand the high temperature blasts of the jet exhaust. This may be a legitimate reason for rigid pavements in certain areas. It cannot justify the overall condemnation of the pavements at other than these relatively small areas.

Some recent surfacing developments may even give us a surfacing which will be resistant to the jet blasts. These will present a relatively high volume cost but will be highly resistant in comparatively thin films. Tests are under way using certain plastic materials which offer possibilities.

PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Pipeline (PL), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways and Harbors (WW), divisions. Papers sponsored by the Board of Direction are identified by the symbols (BD). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper numbers are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 1113 is identified as 1113 (HY6) which indicates that the paper is contained in the sixth issue of the Journal of the Hydraulics Division during 1956.

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c. Discussion of several papers, grouped by Divisions.